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Driven to distraction : when drivers talk on cell phones

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DRIVEN TO DISTRACTION: WHEN DRIVERS TALK ON CELL PHONES

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ABSTRACT

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WHEN DRIVERS TALK ON CELL PHONES

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Cell phone conversation is believed to contribute to accidents by diverting driver attention. Even when visual and biomechanical distractions are eliminated by using hands-free phone, evidence of distraction persists. Conversation is believed to cause cognitive distraction in the "central executive" processes that govern attention timesharing and the ability to adapt highly routine control processes. This study examined the effects of conversational role (listening vs. talking) at varying levels of conversational complexity (simple vs. complex). Twenty-one male and female participants between the ages of 18 and 34 drove a PC-based simulator while engaging in naturalistic conversations using a simulated hands-free phone. Based on driving performance—measured by near misses, collisions, missed traffic events, lane deviation, and speeding—talking impaired driving more than listening, especially during complex conversations. The results suggest that drivers avoid both cell phone conversations in which they are the predominant speaker and those which require complex cognitive processing.

AKNOWLEDGEMENTS

My husband, Michael, and daughter, Sarah, deserve many thanks for their patience.

DEDICATION

To all of the distracted:

"His expression was no longer shocked; he merely looked blank, as if his mind were elsewhere. As if, Brat thought, he were doing sums in his head."

Brat Farrar, by Josephine Tey

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Introduction

Telematics is defined as "wireless voice and data communication between a car and somewhere else (Buderi, 2001, p.78). The term encompasses cellular telephones, global positioning, e-mail, fax, PDA docks, VCRs, and many other devices. Uses for telematic devices vary from safety and roadside assistance, to navigation assistance, to entertainment, and to productivity. The industry's vision of the future is rosy: Revenue from this new market is expected to grow from $5.3 billion in 2001 to $30 billion by 2010 (Buderi, 2001). As one industry representative describes it, telematics systems will "let both driver and passenger check e-mail, consult a personal calendar, and review vehicle maintenance schedules….our vehicles will become not only a safe and comfortable means of transportation but also a digital platform for entertainment and access to a vast quantity of information while traveling" (Zhao, 2002, p.10).

Michael Goodman, chief of driver research and simulation at NHTSA believes that cell phone technology serves as the model for the adoption of automotive telematics (Ashley, 2001). Cell phone ownership has exploded. In January 1985, there were fewer than 100 thousand in the U.S. As of May 2002, there were over 135 million cell phones in use. An estimated 50% of the U. S. population owns a cell phone. Revenue has grown from less than $1 million in 1985 to almost $60 billion in 2001 (Hahn & Dudley, 2002).

An Unresolved Human Factors Issue

A key unresolved point for the growing telematics industry is how to avoid the driver distraction or inattention in general, which causes 25-30% of accidents, according to the National Highway Traffic Safety Administration (Sundeen, 2002; Shelton, 2001).

NHTSA's Goodman believes that "a minimum of 25% of fatal crashes are distraction related" and reports that other researchers put the number at 30 to 50%. He notes that, in general, distraction-related fatal crashes are very underreported because deceased drivers cannot report and surviving drivers are unwilling to report causes because of potential liability (Ashley, 2001, p. 55).

Currently, there are no generally accepted industry guidelines for the design or use of telematic devices, although a few guidelines are emerging for cell phones—e.g., hands-free operation to reduce visual distraction. User interface and safety knowledge lags far behind electronics development. Paul Green, a senior research scientist at University of Michigan's Transportation Research Institute sums up the concern about distraction factor: "There is great excitement about…how these systems might enhance the driving experience. Yet relatively little emphasis has been given to the potential risks associated with the overload these systems might pose to drivers. If action is not taken, a significant number of information-system-related deaths and injuries will result" (Ashley, 2001, p.55).

The Distraction Factor

Even before the advent of cell phones and other telematic devices, driver inattention was named as a cause for 64% of rear-end crashes and associated with following too closely, the cause of 14% of all crashes (Brown et al., 1969). Epidemiological studies concluded that distraction was a leading cause of traffic accidents. In one study, improper lookout and inattention was a leading cause of 2,258 accidents; another study concluded that 37.8% of 723 crashes were caused by driver inattention or perceptual errors. Finally, Strayer, Drews & Johnston (2003) reported that attention errors were the most common factor in left-turn accidents. NHTSA has estimated that "driver inattention or distraction" is responsible for 25% to 30% of police reported traffic crashes—1.2 million crashes per year (Stutts et al., 2003). The assumption common to these epidemiological studies—that if drivers were aware, they would drive as safely as they could and avoid accidents—seems a fair assumption to make, given the potential for pain and injury in any traffic accident.

Cell phones are widely accused of distracting drivers from the road. Drivers themselves seem to be aware of the distraction factor. In the United States, 84% of cell phone users surveyed believed that using a phone while driving is a distraction and increases the likelihood of an accident. Even so, 61% of those surveyed reported that they use their cell phone while driving, and 30% of those characterized their use as frequent (Parkes & Hooijmeijer, 2000). The comments below capture the sense of distraction that drivers experienced while driving & talking a cell phone at the same time:

> Sometimes I'd pull out in front of another car while paying attention to the conversation, and other times, I'd space out on what the person was saying to me while I tried to avoid hitting a pedestrian.
>
> I have traveled 10 or 20 miles while gabbing and, at the conclusion of the call, have zero recollection of how I got from Point A to Point B.

These comments were posted to the National Highway Traffic Safety Association (NHTSA) Driver Distraction Internet Forum web site, a virtual conference held on the Internet between July 5 and August 11, 2000, on the topic of the driver distraction resulting from the explosive growth of in-car telematics (Llaneros, 2000).

A multi-year study by the AAA Foundation for Traffic Safety found that distractions are a common part of everyday driving. Phase I of the study identified potential distracters, including cell phone use. In Phase II, the researchers installed cameras and other monitoring devices in participants' cars in order to see what people really do when driving. AAA found that, excluding conversations with passengers, drivers engaged in potentially distracting behavior 16.1% of the time their vehicles were moving, with cell phone usage accounting for 1.3% of that time (Stutts et al., 2003).

Researchers have established that cell phones are a potential cause of driver distraction, which is associated with an increased risk of accidents. However, the distraction mechanism not well understood, either by drivers or by researchers. The basis for any study of driver distraction must be an understanding of how attention works in the driving task and what factors might cause driver distraction.

Attention Theory and Driving

Driving has been described as a "complex perceptual information-processing task" (Arthur & Doverspike, 1992). At the strategic level, the driver plans the trip and determines the route. At the tactical level, the driver is aware of the rules of the road—e.g., the rules for changing lanes on the freeway. At the operational level, the driver maintains moment-to-moment control of the car. This lowest level of control operates as a feedback loop for keeping the car under control. The driver monitors the traffic scene in order to react to traffic events and signals—e.g., speed control, lane maintenance, braking response, and collision avoidance. At any given moment, the operational level may require attention—e.g., braking when a leading car slows. Driving demands attention on several levels for planning, perception, cognition, task selection, and motor response (Green, 1994).

After sufficient practice, driving may seem to become almost automatic. Its learning pattern is similar to that for automatic tasks. At first, driving requires exclusive concentration, as anyone who learned to drive using a manual transmission knows. Later, it can become highly routine. At times, people drive with hardly any memory of it, especially when following a stream of thought unrelated to driving. The perceptual monitoring component is essentially continuous and usually forgiving of short lapses. With practice, drivers may believe that additional tasks can be added without impairing either the steering or monitoring components of the driving task. They may decide that driving does not require much attention or that their attention is not really divided when they drive while doing a hands-free "thinking" task, like conversing on a cell phone. Driving responses do not meet the criteria for automaticity: responses which no longer impose capacity demands and are not under voluntary control but are triggered by the mere presentation of an appropriate stimulus, regardless of intention. For example, we do not make braking motions with our foot every time we see a Stop sign when in the passenger seat (Pashler, 1998).

The ultimate goal of attention in driving is situation awareness, defined as "the perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). So even when driving feels automatic, it still requires attentional resources to scan the environment and plan responses in order to maintain control, avoid obstacles, and interact safely with other vehicles.

The Attentional "Searchlight"

Attention distributes limited resources among various tasks. Visual attention—predominant in the driving task—has been described as a "searchlight," a relatively narrow focus guided by higher cognitive functions (Pashler, 1998). The searchlight metaphor is based on a human limitation: When we "look at" something, we see fine detail in only a very narrow region of our field of vision. This *foveal region* is comprised of only about 2 degrees if visual angle surrounding the center of fixation. When we look at something in order to extract information for a task, our *useful field of view* (UFOV) is only a little larger than the foveal region—up to 4 degrees of visual angle surrounding the center of fixation (Wickens & Hollands, 2000). When the task is driving, this UFOV seems very small when considered against the area to be covered: the roadway environment on all four sides of the vehicle, where most elements to be looked at are in constant motion. Given the restricted area from which we gather task information, scanning or sampling the environment is an essential part of visual attention. Thus, we must select the part of the environment to which to give attention. Here is an example:

> A new driver of a delivery van is using an electronic map console. The map is hard to use—cluttered, hard to read, and upside down relative to his direction of travel. He focuses too long on it and, while he is "head down" trying to figure out where his next stop is, the car in front of him stops. The driver fails to notice in time and and rear-ends the stopped car (Wickens & Hollands, 2000, p. 1).

The accident resulted from the driver's distraction from his primary task—i.e., driving—by a secondary task that competed for selective visual attention.

"Selective attention" (i.e., perceptual filtering) voluntarily focuses attention on a particular stimulus and excludes others. Studies in visual search and auditory monitoring show that selective attention operates much the same in both modes. Target/distractor discriminations can be performed in parallel and without capacity limitations up to some combined level of complexity, as long as only a single target is presented. People are efficient at perceptual filtering based on simple, physical selection criteria, such as spatial location, pitch, or color; practice and cueing can make single-target search even more efficient. Under conditions that allow effective selections, people choose selective rather than unselective (Pashler, 1998). Visual and auditory selective attention operate similarly to make us efficient at selective attention when searching for a single target and ignoring distractors.

"Divided attention" involves taking in sensory information from several sources at approximately the same time with the goal of monitoring the contents of all channels or to detect the presence of a target. As summarized in Pashler's *The Psychology of Attention,* capacity limits becomes evident when a task requires discriminating targets defined by complex criteria such as fine featural discrimination or correct processing of spatial configurations—e.g., reading a word or performing mental rotations. In addition, target detection impairs the ability to detect other targets for a relatively short period thereafter. When observers attempt to monitor an entire scene, their level of change detection is much lower than their ability to detect a single target. People are extremely poor at monitoring 2 scenes at once. Even within a single perceptual modality, divided attention lowers target/distractor accuracy when there is more than one target, many items to monitor, or if the target and distractor are too similar. When attention is divided, visual and auditory modes operate with similar results, showing capacity limitations once there are multiple targets or scenes to monitor (Pashler, 1998).

Given a choice, we tend to choose selective attention over divided attention, possibly because we are better at target search than monitoring entire scenes. This suggests that under dual-task conditions, especially when both tasks are nearly continuous—like driving and conversing on a cell phone—our natural tendency is to attend to one task more than the other. It is reasonable to assume that we might attend to whichever task seems more demanding.

The next section reviews multitasking and relates human information processing to the demands of driving and conversing on a phone at the same time.

Shared Attentional Resources

Under certain conditions, attention may be shared by two or more concurrent tasks. This kind of "timesharing" works best when task information can be processed in parallel by separate storage and retrieval mechanisms. The work of Baddeley and others suggests that visual and auditory information may be processed separately under certain conditions. The visuospatial sketchpad processes information that can be represented as images and is believed to be separate from the phonological store, which represents information as words or sounds. Visual-spatial and verbal-phonetic codes appear to cooperate rather than compete for working memory resources—i.e., the resources that guide visual attention. For example, Wetherall's driving research indicates that following a (phonological) route list interferes less with driving than following a (visual) map

(Wickens & Hollands, 2000). A spoken route list interfered with driving less than either the written list or the map (Dingus et al., 1997; Srinivasean & Jovanis, 1997).

Although driving and talking on a cell phone may seem to be independent enough to be done in parallel, this is not necessarily the case. Visual and auditory processing are not always independent. In cross-modality tasks, auditory input can capture attention from a visual task—e.g., when a driver attending to the roadway hears his cell phone ring. Sound and speech have so great an ability to capture our attention, even while we are otherwise engaged, that the auditory track has been characterized as "the sentinel of the senses" and is often used to deliver urgent information, like warnings and alerts (Wickens & Hollands, 2000).

The Role of the "Central Executive"

Doing two tasks simultaneously may impair performance on one or both because the tasks compete for *cognitive processing* resources—even if they don't compete for perceptual resources. When considering driving and distraction, the availability of the higher-level "executive" resources to guide the attentional searchlight becomes an important issue. The role of a central executive function is to allocate attentional and information processing resources to each task (Wickens & Hollands, 2000). Cognitive interference may impair multiple task performance even when input and output channels are distributed across perceptual modalities and response effectors (Kahneman, 1973). For example, the central executive has been shown to be susceptible to attention capture by visual and auditory *cues*—indicators, usually with abrupt onset, that signal the location where a visual target will shortly appear. Cues are acknowledged to be such a powerful means of shifting visual attention toward a target that they are sometimes not subject to voluntary control. Studies indicate that cues that occur within the foveal area, where attention is already directed, can be voluntary suppressed, suggesting that processing these central cues requires more cognitive resources than processing peripheral cues (Jonides, 1981). But peripheral cues—cues that appear outside the UFOV—have a powerful attention-capturing power that is resistant to voluntary suppression. Under certain conditions, an abrupt visual onset automatically captures attention—specifically, when not attending to anything in particular—i.e., in "diffuse attention mode" (Yantis & Jonides, 1990). Given the amount of information and the external pacing of events, we might reasonably consider monitoring the traffic scene an example of "diffuse attention mode." In that case, a driver is potentially set up for distraction by a peripheral cue (visual or auditory) that will distract attention from what is going on directly in his field of view:

> [W]hen the operator has many tasks to perform—keeping the car in the lane, searching for the exit sign, and trying to plan the next route to take—he must select a strategy for *dividing* attention or allocating resources between these different tasks or mental operations. When the total attention demand of these tasks is excessive, one task or another must suffer. So, for example, if the driver becomes preoccupied...he may still fail to detect the stalled vehicle even if his eyes are looking forward (Wickens & Hollands, 2000, p. 14).

The Response-Selection "Bottleneck"

During multi-tasking, costs may arise as a consequence of competition for either perceptual or central processing capacity. In the case of perceptual capacity, overload can be mitigated by presenting stimuli through parallel input modalities or using cueing. However, these methods do not work when applied to tasks that require central processing resources (Pashler, 1998). Although perceptual attention systems seem to be able to share resources, the response-related processing seems to be fundamentally different.

Research summarized by Pashler indicates that response-related processing (i.e., the central executive function) operates by sharing access time—i.e., by switching or queuing—thus incurring a cost. In short, people seem unable to plan (i.e., select) 2 responses at the same time. Judgment tasks appear to require exclusive but intermittent access to central decision-making machinery (Pashler, 1998). When driving, the human operator functions as a correction servo, monitoring and making intermittent correction responses as required. Studies of intermittency indicate that certain types of mental processing cannot be done simultaneously, but are subject to a central processing bottleneck for response selection (Craik, 1947; Pashler, 1998). The bottleneck seems to apply even when tasks involve different input modalities and different types of responses and to a variety of cognitive operations: response selection (i.e., planning); perceptual comparisons based on complex criteria; and manipulations of certain types, including comparison of line lengths, mental rotation, and memory retrieval. For highly practiced tasks, switching may occur more quickly, but response planning does not become simultaneous (Pashler, 1998).

Response selection does seem able to operate in parallel with storing unrelated information in short-term memory (STM). For example, a completely unrelated task, such as sorting cards or selecting a response to a tone, does not seem to impede transfer of spoken or visually perceived information into articulatory or visual STM (Baddeley et al., 1969; Pashler, 1998). However, long-term memory (LTM) retrieval and storage are subject to the same bottleneck as response selection. When a stimulus is used as a probe to recall associated information from memory, another recall process that would yield a different output cannot start until the first has finished. Of course, when the information to be retrieved consists of a response, the postponement takes the form of a response-selection bottleneck. When LTM retrieval, such as producing instances of a small category (e.g., farm animals) is paired with a concurrent serial reaction-choice task, the trend is for the successful memory retrieval to be little affected and for the concurrent reaction task to be delayed. At a maximum rate of performance, selection of responses will be rate limiting, whereas other stages of processing may sometimes overlap: The total rate at which information can be processed is the same whether 1 or 2 tasks are performed (Pashler, 1998).

A secondary task can interfere with preparation for the primary task. In Kahneman, Beatty, & Pollack (1967), participants watched sequences of letters looking for *Ks* while adding 1 to every digit of a spoken 4-digit number (e.g., for spoken number "4236," the response is "5347"). Both tasks suffered, but performance on the (primary) visual monitoring task fell from 88.5% correct to 68.5% correct, leading to the conclusion that the arithmetic task may have prevented participants from "periodically reminding themselves to look for *K*s." Similarity exacerbates dual-task interference. Sharing an input modality, an output modality, or type of choice or judgment required increases interference (Pashler, 1998). Performance on the same type of auditory task performed on 2 channels is much worse than for tasks performed on different channels. Similarity and overlap of codes may be a severe problem when people switch back and forth between continuous tasks (Pashler, 1998).

There is evidence that the same limitations in decision and response selection govern continuous tasks. Sensorimotor tasks, such as driving and conversation, produce apparently continuous streams of behavior that actually require intermittent, or discontinuous, central processing when planning movements or responses. Central processing limitations are revealed when people try to concurrently select and produce 2 independent speeded responses (Pashler, 1998). When continuous tasks require manual response, the manual response shows the effect of delayed access to response planning resources. Fisher paired a serial task with and intermittent task. The serial task was a compatible manual response to visual stimuli; each response triggered the next stimulus. The arithmetic task required adding 7 to each intermittently presented spoken digit and saying the sum aloud. The speed of the manual response was heavily dependent on its relationship to the digit responses. The marked slowing of the first manual response after each digit response was taken to be strong evidence for task switching (Pashler, 1998).

In similar studies by Schouten, Kalsbeek, & Leopold and Kalsbeek & Sykes, the primary task involved pressing a left or right foot pedal depending on the pitch of a tone. Participants were told to give priority to the primary task and allowed to practice until the task became familiar. Experimenters then determined a maximum rate at which participants could perform the primary task alone with a low rate of error. Participants were then given various secondary tasks while the pace of the primary task was varied. When the secondary tasks required simple motor behavior with little response choice (e.g., putting nuts and washers on screws), participants performed the second task at near maximum rate, regardless of the pace of the primary task. When the secondary task required responding vocally with the sum of 2 visually presented numbers (e.g., 4 + 7 =?), performance of the second task was cut in half, as the primary task increased to its maximum. Other secondary tasks included spontaneous handwriting, the Porteus maze test, and making key press responses to lights. When the secondary task was spontaneous handwriting (i.e., write whatever comes to mind), both content and writing style became more primitive as the rate of the primary task (foot pedal responses to high and low tones) increased. Participants began by writing complete sentences; as the primary task sped up, they wrote repeated words and, finally, repeated letters. Both the Porteus maze test and key press responses showed the same pattern of impairment as the primary task rate increased (Pashler, 1998).

Interestingly, the response-selection operation is so lacking in salience that people hardly notice it or any difficulty associated with it. In his review of attention theory, Pashler uses the example of drinking coffee while having a conversation. One might plan to move the coffee cup to the mouth, then plan an utterance and even finish speaking before the cup reaches the lips. People may not notice dual-task interference because they are usually oblivious to a brief delay that does not seriously disrupt performance. Also, practice may make interference less noticeable because the task requires less conscious preparation (Pashler, 1998).

Pashler defines “distraction” as attention that is “directed or grabbed without any voluntary choice having taken place” (Pashler, 1998, p.3). He points out an important consequence: "failure to remember to adapt to the proper task set at the proper time" (Pashler, 1998, p. 379). Active preparatory work seems to be necessary to adopt and maintain a task set. People mention in connection with highly routine tasks having done them with scarcely any awareness, particularly when following a stream of thought unrelated to the task (Pashler, 1998).

The studies above indicate that when a primary task occupies the central decision-making machinery, the residual performance for the secondary task reflected inter-digitated (and often inadequate) access to this machinery on the part of the secondary task. When pairing a cell phone conversation with driving, the key issue is whether driving always remains the primary task. If it becomes the secondary task at any point, it will show impairment to the extent that it must wait for the conversation to release response-selection resources. Based on the studies above, the driver is likely not to notice when conversation interferes with driving. This is the condition we would call "distraction."

Looking Without Seeing: Inattentional Blindness and Change Blindness

Why would a driver fail to see a stalled car ahead of him—even if his eyes were looking forward? Although the relation of visual attention to visual perception (i.e., seeing) is not yet clear, *inattentional blindness* and *change blindness* are considered to be different aspects of an induced blindness—to the presence of a stimulus or a change in the stimulus, respectively—created by the diversion of attentional resources at fixation.

Inattentional blindness has been defined as "the experience of looking without seeing, or functional blindness, during moments of intense concentration or absorption"

(Mack & Rock, 1998). The comments at the beginning of this review suggest that the drivers who made them suffered from temporary inattentional blindness while driving and talking on a cell phone. This form of inattentional blindness seems to be experienced at one time or another by most people who drive while talking on a cell phone. Mack and Rock discovered the phenomenon while studying which properties of perceptual objects may be perceived pre-attentively. To their surprise they found that, on average, 25% of observers failed to see critical stimuli under certain conditions: "A suprathreshold stimulus present for 200 msec within 2 degrees of fixation was not detected when the subjects were not expecting it and were attending to some other object" (Mack & Rock, 1998). They concluded that, at least when looking directly at something, there was no perception without attention. In later experiments, they increased the degree of inattentional blindness within the UFOV to 60%-80% when attention was captured by peripheral visual stimuli. And inattention within the UFOV became virtually 100% when attention was captured outside the UFOV *and* the observer deliberately inhibits attention to the point of fixation. In these studies, Mack and Rock observed inattention to stimuli directly in the field of vision that was caused by visual distraction. They had no direct data using another modality. However, they believed that inattentional blindness could also result when attention was captured in the same way by sensory objects *in other modalities or by ideas* [emphasis added]. It is difficult to reduce errors due to inattentional blindness because it happens automatically, without our awareness, when conspicuous stimuli capture our attention from what's going on where our eyes are looking.

Based on these studies, the inattentional blindness phenomenon offers a possible explanation for why cell phone use distracts drivers: It distracts selective attention from stimuli directly within the field of view while the driver is in diffuse attention mode.

Change blindness is a failure to perceive changes in a scene that is being monitored. Change blindness studies indicate that the visual perception of change requires selective visual attention. According to studies, under natural, undirected viewing conditions, we "see" only the gist of a scene. In one study, 67% of the participants failed to notice significant changes of actor in a film clip. They had not been cued to look for a change in actor, so they saw only that someone had walked through a door and sat down (Rensink, 2000).

Clearly, driving requires attention on several different levels—strategic (planning), tactical (rules), and operational (moment-to-moment control). Because attentional resources are limited, they are governed by a central response-planning process. This process does two jobs. First, it directs selective attention to what is going on in the relatively narrow useful field of view. Second, when stimuli can use separate attentional stores, the central process governs the sharing of perceptual resources. Studies indicate that the perception of presence and the perception of change are mediated by attention—i.e., while driving, selective attention is necessary to perceive both detail and change. When attention is distracted, the contents of visual memory are overwritten and change goes unnoticed (Rensink et al., 1997). As the following cell phone studies demonstrate—and as any driver whose mind wanders knows—looking is not enough.

Considered together, inattentional blindness and change blindness suggest a mechanism that explains how talking on a cell phone affects driving performance. The studies reviewed here present a concept of "looking without seeing" caused by the distraction of selective attention. The concepts are persuasive because they seem to relate to the current study, even though the studies did not focus on driving or cell phone use. However, the present study is not designed to examine these concepts, since the visual attention collection and analysis tools required for such an examination are not being used. The current study focuses instead on response planning and production limitations.

Epidemiological Studies of Cell Phone Use

Epidemiological studies examine accident data looking for data that associates cell phone use with accidents. By their nature, such studies cannot establish causal relationships, but can only look for statistical associations. They are useful in that they associate cell phone use with traffic mishaps and point out issues for further study.

Studies of accident data suggest that cell phones do contribute to traffic accidents. In a 2002 meta-analysis entitled *The risk of using a mobile phone while driving*, The Royal Society for the Prevention of Accidents (RoSPA) concluded that the use of cell phones impaired driving performance. After reviewing 55 studies conducted between 1993 and 2001, RoSPA concluded that using a cell phone impairs driving in the following areas: maintenance of lane position, maintenance of appropriate and predictable speed, maintenance of appropriate following distance, reaction time, judgment and acceptance of safety gaps, and general awareness of traffic.

One epidemiological study that is often cited in articles on cell phone use was published by Redelmeier and Tibishrani in 1997. Their study of cell phones records of 699 individuals involved in accidents found that 24% were using the phone within 10 minutes before their accidents—i.e., 100% of the participants had had accidents and 24% of them used a cell phone just before the accident. The authors characterized this association as a "fourfold increase" in the likelihood of having an accident and associated this statistic to a similar statistic for driving with a blood alcohol level above the legal limit—i.e., "[the] relative risk is similar to the hazard associated with driving with a blood alcohol level at the legal limit" (Redelmeier & Tibishirani, 1997, p. 456). Several other studies associated frequency of cell phone use with a rise in accidents. One study examined a small sample size of 200—100 of whom had had accidents and 100 of whom had not. This study found that conversing on the cell phone while driving for more than 50 minutes per month was associated with a 5.59-fold increase in the risk of having an accident. When compared to control cases, accident cases spent about twice as much time per month talking on the cell phone while driving and appeared to engage in considerably more business and intense conversations (Volanti & Marshall, 1996). In 2000, University of North Carolina's Highway Safety Research Center (HSRC) did a computer search of all North Carolina crash report narratives between 1/1/96 and 8/31/00. They found that the frequency with which cell phones were mentioned went from 22 in 1996 to 231 in the first 8 months of 2000. Dreyer, Loughlin, & Rothman analyzed the billing records of 285,561 phone subscribers and found that mortality rates from motor vehicle crashes increased with the increase in minutes of cell phone use per day. They also found that mortality rates decreased with increasing numbers of years of cell phone service (Reinfurt, Fegeanes & Hunter, 2001).

Another study analyzed 28 cell-phone-related crashes—11 from the Fatality Analysis Reporting System (FARS) or the National Automotive Sampling System (NASS) and 17 from other sources. Cell phone users were at fault in all 28 crashes: 15 occurred when the driver strayed out of the lane, 8 occurred with stopped vehicles in the same lane, and 5 occurred when drivers failed to stop for red lights (Goodman et al., 1997). This study is particularly interesting because of the nature of the accidents. Because all 3 types of accidents are characterized by failure to "see" what was going on in the roadway, inattentional blindness and change blindness may have been factors in these accidents.

Epidemiological studies provide an indication that cell phone use distracts drivers and that an increase in cell phone use is associated with an increase of accidents characterized by lapses of selective attention. The next section reviews controlled studies of driver performance that examine why lapses in attention occur during cell phone conversations.

Studies of Driver Performance

Methodology

As of 1994, there was no generally accepted model for driving behavior or for choosing methods and measures with which to evaluate the impact of in-car systems on driving performance. In 1994, Paul Green, at University of Michigan's Transportation Research Institute, conducted a measures and methods project in order to develop a model that predicts driver performance. Green reviewed studies done before 1993 that relate to the safety and usability of in-car systems and recommended that studies evaluate driver performance based on measures that focus on the navigation task—i.e., traffic negotiation and collision avoidance. The list below is based on Green's recommendations and additional recommendations from later reviews (Green, 1994; Goodman et al., 1997; Stutts et al., 2003):

- Objectives measures that reflect vehicle control and guidance—e.g., speed, lane position, visual sampling rate, acceleration rate, deceleration rate, near misses, collisions and time-sharing of driving and a secondary task

- Objective measures of how the driver preserves a safety envelope based on situation awareness—e.g., reaction time; following distance; gap judgment and acceptance; perception of traffic signals, signs, and peripheral events

- Subjective workload indices—e.g., SWAT and NASA TLX

The measures above have been generally accepted and used in studies that evaluate driver performance during cell phone use.

The lab vs. the road. Controlled studies have been done in the laboratory using driving simulators of varying degrees of fidelity, on the road under controlled conditions (i.e., on a track, an abandoned airstrip, or an unused roadway), and on the road under naturalistic conditions (i.e., in a car equipped with data-gathering equipment). Although researchers generally agree that data is best gathered under real-life conditions, it is difficult to do so. Safety is an obvious issue for on-the-road studies, especially when introducing secondary tasks that truly distract from the driving task. Conversely, a naturalistic study, in which no controls are introduced, provides data that is difficult to generalize. Lab studies provide "cleaner" and more generalizable data, but researchers may have reason to question how seriously drivers treat a simulated driving task, especially when a low-fidelity simulator is used (Alm & Nilsson, 1994).

Although the conditions under which key studies have been conducted differ, they have certain factors in common. All manipulate cell-phone variables: Some used a hand-held phone; some used a hands-free phone (or "open microphone" simulation); and some used both. The studies used various secondary tasks. Earlier studies tended to focus on visual or physical tasks, such as dialing a hand-held phone. Later studies focused on cognitive distraction using secondary tasks meant to distract the central executive and capture attention from the driving task.

Four types of distraction. Overall, performance studies examine the effects of four types of driver distraction: visual, biomechanical, auditory, and cognitive (Ashley, 2001). The first two types received early attention and are fairly well understood. However, auditory and cognitive distraction are less well understood—and probably related.

Studies of Visual and Biomechanical Distraction

Visual and biomechanical distraction studies focus on the amount of time the driver's eyes are on the road and hands are on the wheel. From these studies—most of them using hand-held phones—we know that visual and manual tasks such as reaching for, dialing, and holding a cell phone impair driving performance (Brookhuis, deVries & deWaard, 1991; Briem & Hedman, 1995; Reed & Green, 1999).

Hand-held operation. In a study conducted by Zwahlen, Adams & Schwartz on an unused airport runway, participants dialed an 11-digit number on a phone mounted on the dashboard (i.e., head up) or level with the seat (i.e., head down) while accelerating to 40 MPH in the straightest path possible. In different trials, participants were allowed or not allowed to check the roadway while dialing. Driving performance as measured by lateral path deviation was impaired most when dialing the low-mounted phone without being able to look at runway and least when dialing phone on dash and able to look. To put this study into perspective, 11.9% of the dialing tasks done in the experiment would have resulted in traveling outside a10-ft lane of traffic, into oncoming traffic or off the road; 1.9% would have caused the driver to travel outside a 12-foot lane (Goodman et al., 1997).

In another study, participants dialed long numbers on a hand-held phone or a phone mounted on the dash in the driver's line of sight. Manual dialing under either condition interfered with the driver's ability to follow the road. However, dialing the dash-mounted phone interfered less (Department of California Highway Patrol, 1987). A study using both hand-held and hands-free phones found that both types of phones caused larger deviations in lane position than not using a phone—although the effect was larger for manual dialing than for voice-activated dialing (Serafin et al., 1993).

Another study focused on the performance effects of various phone operations. Participants drove a simulator under conditions that included straight and curving roadways and obstacles requiring lane changes. The phone task featured a number of variables: phone location (mounted within the line of sight on the dash vs. on the center console out of the participant's peripheral line of vision), hand held vs. voice activated, and initiating a call vs. answering. Not surprisingly, manual manipulation of the console-mounted phone caused the greatest performance decrease. In straight lane tracking, manual dialing of the console-mounted phone doubled the likelihood of exceeding the lane for the 25-55 group and tripled the likelihood for the over-55 group. Manual dialing of the dash-mounted phone doubled the likelihood for both age groups. Answering a phone call, under all conditions, resulted in an increase of less than 10% of the probability of exceeding the lane. Unfortunately, the authors did not present results for the curved roadway condition, due to a problem with the lane-tracking measure. In this study "lane tracking" was not a direct measure of the number of times a driver traveled outside the lane, but was extrapolated based on standard deviation (SD) from a centered lane position. A probability of exceeding the lane was based on variations of SD from a centered lane position. As the authors acknowledged, drivers do not stay in the center of the lane when driving curved roadways, so the measure failed to give clear results under that condition. The effect of the phone task when obstacles appeared in the roadway were clearer: Manual dialing made a driver 5 times more likely to hit the obstacle if the phone was mounted in the console, but only 1.6 times more likely if on the dash. As a basis for comparison, participants manually tuned a radio while driving. This task was less distracting than cell phone use in all cases except one: Tuning the radio impaired performance more than answering a phone call (Stein, Parseghian & Allen, 1987).

The authors of an on-road study with an instrumented vehicle, felt that the tactical level of driving is most affected by telephoning—e.g., hand-held phones caused "violent" variations in the amount and amplitude of steering wheel movements during dialing. The tactical level involves reactions to other cars, checking the rear view mirror, adapting to speed of car in front, braking reactions. The researchers observed what they characterized as a "minimum strategy" that was not affected by the telephoning task (Brookhuis, deVries & deWaard, 1991).

The authors of another study felt that using a hand held phone actually improved tactical control of the vehicle. While using the phone, participants drove more slowly and steadily, as measured by standard deviations of speed and lateral position. In addition, as measured by standard deviations of steering wheel angle, talking was more difficult than dialing the phone (Green, Hoekstra & Williams, 1993).

In another study, participants showed varied responses to using a cell phone during a pursuit task. Of the 17 participants, 2 were able to use the phone and maintain a constant speed; 9 had problems doing both tasks simultaneously and coped by slowing down to give themselves more time. The other 6 seemed to suffer "mental overload" and responded by sometimes giving the driving task more importance and sometimes giving the phone conversation more importance. At different times, this resulted in speed decrease; at other times, it resulted in speed increase (Pachiaudi & Chapon, 1994).

The peripheral interference hypothesis. Taken together, studies of hand-held phones confirm that manual operation impacts driving. In particular, head-down dialing keeps the driver's visual attention away from the roadway long enough to impair reaction time and lane keeping. Studies also indicate that drivers attempt to compensate for the distraction in order to maintain tactical control of the vehicle. It seem reasonable to assume that, when the distractions are visual and biomechanical—i.e., eyes *not* on the road and hands *not* on the wheel—drivers are aware of being distracted, and the knowledge becomes part of the operational feedback loop that governs tactical and operational control of the vehicle. Based on such studies, a plausible hypothesis emerged that invited comparison between cell phone use and radio use, applying makeup, etc. This "peripheral interference hypothesis" has been tacitly endorsed by legislative initiatives that outlaw hand-held phones but place no restrictions on hands-free phones (Strayer & Johnston, 2001).

Other studies, reviewed next, focus on auditory and cognitive distractions. These studies have found that drivers are still distracted from driving during phone use, even when visual and biomechanical distractions are eliminated by using hands-free phones.

Studies of Auditory and Cognitive Distraction

The attentional hypothesis. The attentional hypothesis attributes impairment to the diversion of attention from driving to the phone conversation. The hypothesis is supported by lab studies that use auditory-based secondary tasks to disrupt the driving task, which is primarily visual. Interestingly, there seems to have been little study of whether conversation with a passenger in the car distracts. While meta-analyses of cell phone research mention "passenger interaction" along with other potential distractions, they do not report studies that isolated conversing from other interaction (Green, 1994; RoSPA, 2002; Stutts, 2003). Instead, research shows that simulated driving tasks are disrupted by the following auditory-based tasks: reasoning tasks (Brown et al., 1969), mental arithmetic (McKnight & McKnight, 1993), working memory tasks (Alm &

Nilsson, 1994; Briem & Hedman, 1995), & visual-spatial tasks (Recarte & Nunes, 2000). Also, lab studies of selective-attention tasks (Arthur & Doverspike, 1992) and attention-switching tasks (Elander, West & French, 1993; Moss & Triggs, 1997;Strayer, Drews & Johnston, 2002) do seem to predict traffic accidents. As Figure 1 shows, if a conversational response selection "grabs" the single-channel response planning machinery first, a driving response may be delayed.

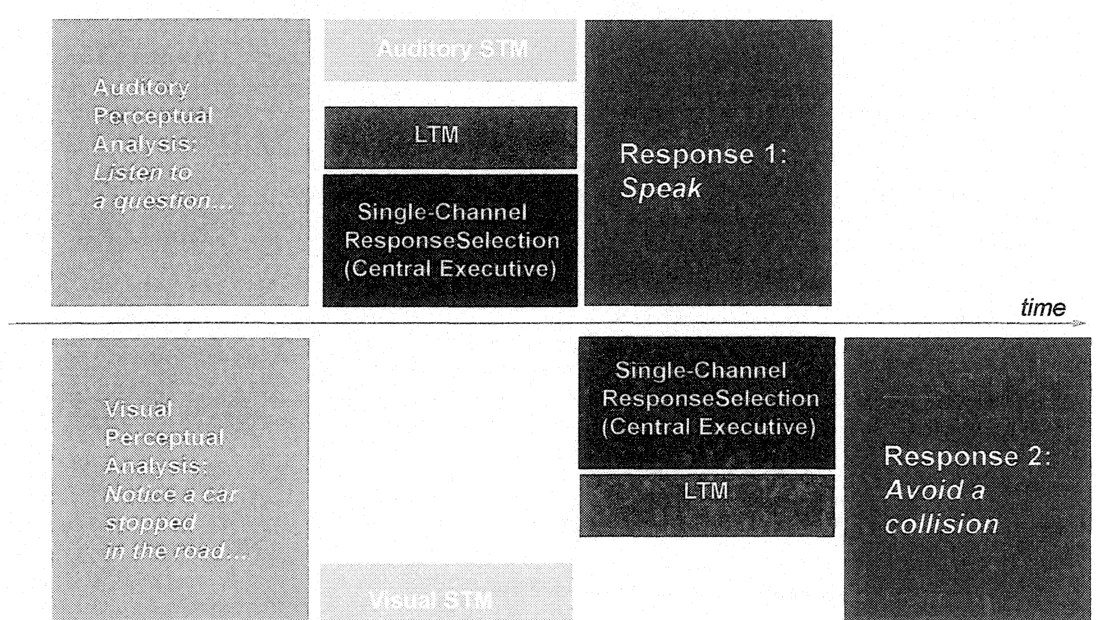

Figure 1. How the response-planning bottleneck works.

Studies by David Strayer and associates at the University of Utah have compared reaction times for driving only and for driving while using a hands-free cell phone. When drivers were on the phone, their reactions (e.g., braking in response to the lead car slowing) were 18% slower, following distance was 12% greater, and they took 17% longer to recover speed lost during braking. The fact that driving performance was impaired suggested that the locus of the distraction was at a central attentional level and was not due solely to structural interference or overload of a perceptual or response channel. Reaction times showed no significant difference between participants using hand-held phones and those using hands-free phones (Strayer, Drews & Johnston, 2003).

For most of us, the low-level operational parts of driving (e.g., lane keeping, headway, speed, etc.) become highly routine. Early models characterized drivers as servo-correction mechanisms who continually attend to the steering task. The attentional hypothesis maintains that distraction affects the supervisory attentional system that manages situations in which a decision needs to be made to correct or modify automatic sequences (Radeborg, Briem & Hedman, 1999). Driving is a task that makes heavy demands on this system. Distraction at the cognitive level affects the higher-order functions, such as monitoring and situation awareness, that allow drivers to react quickly to unexpected events. An interesting lane-keeping study by Godthelp, Milgram & Blaauw (1984) indicated that drivers sample the road scene intermittently, make corrections, then do not sample for a while. In this study, the experimenter found that drivers sampled the road at rates that maintained a constant relative safety margin based on how long it would take to travel out of the lane at the driver's current speed. The sampling rate is governed by the supervisory attentional system. If distraction disrupts the sampling rate, the chance of an accident increases.

The attentional hypothesis points to the central executive as the location of cognitive distraction and suggests that even hands-free cell phone use impairs monitoring, situation awareness, and the ability to react to unexpected events while driving.

Measuring cognitive distraction. Cognitive distraction is harder to measure than biomechanical or visual distraction because it can't be measured by the classic measures of visual inattention—i.e., short gaze or looking away. Indeed, fixed gaze, the classic indicator of attentional focus, may at times indicate cognitive distraction. In fact, driver eye fixation data in naturalistic driving studies show an increased tendency to fixate directly ahead when talking on a cell phone (Harbluk, Noy & Eiszenmann, 2002). But, as we know, looking isn't seeing.

In its naturalistic driving study, which monitored participants driving their own vehicles, AAA found that while talking and listening on the cell phone, participants' hands were off the wheel 6.97% of the time—up from 1.35% when the phone was not in use. However, while talking and listening, the drivers' eyes were distracted from the road (e.g., looking inside the car) only 1.35% of the time, *down* from 2.65% when the phone was not in use. Participants actually kept their eyes on the road more when using the cell phone. Unfortunately, the AAA experimenters were not able to measure cognitive distraction. The methodology used did not allow the experimenters to evaluate whether a fixed gaze indicated attentional focus or inattentional blindness. They did point out cognitive distraction as an important factor that may pose the greatest risk to driving safety (Stutts et al., 2003).

Driving impairment as induced by distraction has been associated with reduced attention to information that falls directly in the line of gaze while talking on a cell phone—drivers react sluggishly to vehicles braking in front of them, miss traffic signals, do not notice billboards and other signs in the driving environment even when they looked right at them while driving and talking on the phone. The interference showed a medium-to-large effect on driving performance (Strayer, Drews & Johnston, 2003).

A University of Rhode Island study by Sodhi & Cohen, which analyzed drivers' eye movements while talking on cell phones, found that drivers tend to stop scanning the road and focus straight ahead—essentially, developing tunnel vision—while doing cognitive tasks like remembering a list of items, calculating in one's head, or using a cell phone. The tunnel vision did not end when the conversation did, but continued for a short time afterward. The experimenters' conclusion was that cognitive distraction was the real problem: "The issue isn't about holding the phone or not holding it. It is one about being involved in an intense task while being involved in another intense task" (Stark & Hasbun, 2002, p. 2).

In a similar study, Recartes and Nunes (2000) found eye-freezing responses and marked horizontal and vertical reduction of the visual inspection window while performing mental rotations. From a single-task state (driving only), the window shrank progressively when the participant drove while doing a verbal task, then drove while doing a visual/spatial task. The inspection window shrank to 50% of normal during the visual/spatial task, when the driver was asked to simultaneously imagine letters from a letter (e.g., N) and say whether it remains unaltered when rotated vertically or rotated vertically or whether the letter is "open" (e.g., like the numbers 3 or 5) or closed (e.g., like the numbers 6 or 0).

These studies indicate that drivers may experience inattentional and/or change blindness while conversing on a cell phone. Drivers are looking at the road but are not necessarily seeing traffic events that occur during the conversation. They may be unaware of changes in a scene even when they occur in full view—i.e., in the foveal range (McCarley et al., 2001).

Driver dissociation. Studies show that drivers do not believe that hands-free cell phone conversations affected their own driving performance—even though their performance on driving simulators was significantly worse during both simple and complex conversations (Goodman et al., 1997; RoSPA, 2002). For example, braking reaction time in a vehicle-following task slowed by 30% without a corresponding effect in the driver's subjective perception of performance or workload (Lee et al., 2001). Strayer, Drews and Johnston (2003) also observed this effect. About half of their participants commented that they found it no more difficult to drive while talking on a hands-free cell phone. Participants reported having seen others driving erratically but rarely, if ever, thought that their own driving was impaired.

The dissociation between performance and perception is a common phenomenon (Andre & Wickens, 1995). We also know that involuntary reactions are notoriously hard for human operators to control. Cognitive distraction is linked to involuntary control over attention—the "mind's eye"—which can be shifted without shifting eye position. An involuntary shift of attention can be caused by powerful cues—particularly auditory cues, such as a cell phone ringing or an engaging speech-based interaction (Jonides, 1981). This shift may occur while formulating a response, committing directions to memory, or contemplating a business problem—all can diminish awareness of the driving situation (Ashley, 2001). Drivers do not notice the distraction or do not notice its extent.

Possibly, the low-level operational tasks (e.g., steering, looking at the road, hands on the wheel, lane keeping) become so highly automated that drivers become less aware of the attentional demands of monitoring the roadway. As one researcher characterized the problem: Drivers may dissociate the perceived vs. actual cognitive demands of speech-based interface (Lee et al., 2001). After all, what we do not perceive, we cannot control.

During cell phone use, a driver's gaze may be fixed on the roadway. In this case, though, the fixed gaze may not mean that the driver's attention is focused on driving but that the driver is suffering from cognitive distraction. When this happens, drivers are often not aware of the distraction, or its extent. This suggests that the distraction involves an involuntary shift of the "mind's eye" during cell phone use. The next question, then, focuses on what causes an involuntary attention shift away from driving during cell phone use.

Speech-based interaction. Reaching for, holding, and dialing the phone do not account for the bulk of time spent on using the phone—conversation does. As Strayer and Johnston put it, cell phone use "disrupts performance by diverting attention to an engaging context other than driving" (Strayer & Johnston, 2001, p. 466). Another researcher was more emphatic:

> Even if you have a cell phone that's not held by hand and can be dialed by voice, you still have a really big conflict because when you're driving you need to be looking at various different places. You need to be reading signs. You need to be talking to yourself—through your mental speech—to make decisions about where to go with your car. And there's no way do to that while on the cell phone because you have to use your "inner ears" and "inner speech" and even your "inner eyes" to imagine what the person on the phone is talking about (Anderson, 2001).

Speech-based interaction—in this case, conversation—may be a key to cognitive distraction. Research indicates that something about speech-based interaction distracts attention at the "central executive" level. In several recent studies, listening to spoken material—radio broadcasts or books on tape—does not compare to conversing on a cell phone on a casual, current-interest topic in ability to impair driving performance. When participants were actively engaged in conversation, tracking errors increased, reaction time slowed by 25% and the number of missed signals *doubled* (Strayer & Johnston, 2001; Strayer, Drews, Albert, & Johnston, 2001). In a follow-on study using a high-fidelity driving simulator, participants were even more likely to be involved in accidents, missed more signals, and reacted slowly to changing traffic patterns. High-density traffic exacerbated these effects (Strayer, Drews & Johnston, 2002).

In another study, during hands-free cell phone use in "relatively easy" driving tasks, participants reacted significantly more slowly, while on the phone, to unexpected events in the first 2 minutes of conversation and were, for much of the conversation, unaware of traffic movements around them. The difference in reactions between the single vs. dual task conditions indicated impairment of the higher-order functions that maintain a clear picture of traffic situations. In the car-following task, participants were slower to adapt to a decrease in speed from 80 km/h to 50 km/h when engaged in a cell phone conversation. Participants were also unable to answer probe questions—e.g., "Can you tell me what other traffic was surrounding you just before I stopped the simulator?" and "Was the car in your rear-view mirror driving faster than you or not?"—asked at several points in the driving session. The number of correct answers dropped a further

50% when the probe questions interrupted a cell phone conversation (Parkes & Hooijmier, 2000).

Conversation seems to hinder attentional guidance during searches, making search less efficient and affecting the number of misses. McCarley et al. (2001) found that scanning for change—an important part of monitoring the traffic scene—was impaired during hands-free cell phone conversation. As measured by the number of saccades necessary to detect and respond to change, search becomes less efficient during conversation. More importantly, most errors were misses, not false positives. The researchers pointed out that interference was cognitive, not structural, because input/output were auditory (not visual) and hands-free.

In a study by the Insurance Council of British Columbia (2001), listening and responding to messages impaired driving performance—apparently by preventing normal adjustment to unfamiliar or complex driving conditions. In this study, commonly encountered traffic choices (e.g., responding to an amber signal) tended to elicit conservative decision-making. On the other hand, less common events (e.g., weaving and left turning) elicited a significantly riskier decision-making and driving performance. Participants driving on a closed track under dry/wet conditions, encountered 3 driving tasks of varying complexity: (1) an amber traffic light, which they must either stop for or drive through; (2) popup targets, which required a sudden weaving maneuver; and (3) a left-turn task, which required judging accepting or rejecting a gap in oncoming traffic as being large enough to allow a safe turn. Hands-free cell phone conversation was simulated by 2 types of auditory tasks: (1) a verbal/semantic task, which required abstract thinking and (2) a visual-spatial task, which required participants to visualize elements. Before each "conversation," participants were given a context—e.g., "means happiness" for the verbal/semantic task or "smaller than a dime" for the visual-spatial task—followed by a string of words. In response, drivers stated "yes" or "no" as to whether each word met the criterion in effect for that conversation.

When engaged in conversation at the amber signal, drivers seemed to make an effort to compensate for any cognitive distraction. They reacted almost automatically, slowing earlier if they planned to stop or accelerating harder if they planned to run the light. At the weaving maneuver—less familiar and more complex—drivers engaged in conversation took longer to begin slowing down and went through the maneuver faster, with less adjustment for staying inside the lane. At the left turn, drivers engaged in conversation displayed significantly riskier behavior than those who were not conversing. They accepted shorter gaps in oncoming traffic and, on wet pavement, made no adjustments at all (ICBC, 2001).

The ICBC study specifically linked conversation that requires active cognitive engagement to an impaired ability to adjust to new or complex roadway events. During conversations, drivers responded almost automatically to familiar events and gave themselves extra time when making less familiar responses. However, they seemed unable to respond to the situation that required them to process new roadway information while talking on the phone.

The RoSPA and NHTSA meta-analyses summarized the results of voice communications studies. RoSPA's review stated that the distraction occurs at the central executive level and impairs situation awareness. When a driver is on the phone, it takes longer to detect and respond to changes in the environment, such as a vehicle braking in front; maintenance of lane position is impaired; drivers may have little awareness of what is happening around them; hands-free telephoning provides no significant advantage. Other potential distractors (e.g., tuning a radio, listening to books on tape, conversing with a passenger) do not impair driving to the same extent (RoSPA, 2002). The 1997 NHTSA review states that cognitively demanding conversations appeared to increase braking reaction times, indicating a reduction in situation awareness rather than an effect on vehicle control *per se*. The review pointed out the need to understand the characteristics of cell phone communications—e.g., frequency, duration, content—that normally arise in the real world in order to better represent them in future studies (Goodman et al., 1997).

Only a few studies have examined specific conversational characteristics for keys to the distraction effect. However, there is evidence of increased distraction during conversations that require active participation and engage the driver's attention.

Engaging conversations. Complex conversations seem to affect driving performance more than simple ones. However, there is no clear definition of what makes a conversation simple vs. complex. Some studies use working memory tasks to simulate conversations that are variously characterized as "complex," "intense," or "cognitively demanding." Verbally presented working memory tasks include versions of the Baddeley Working Memory Span Test, math computations, mental rotation, "in previous list" recognition, sentence vs. nonsense, and repeating the subject or object of specified sentences in a group of sentences.

For example, McKnight and McKnight (1993) used verbally presented math and short-term memory problems to simulate "intense" conversation. Participants were asked to do strings of simple computations in their heads—e.g., $2 + 3 + 4 + 1/2 + 3 + 4 + 6 = n$). The tasks consisted of listening to a list of 5 or 6 digits, then telling the experimenter whether certain digits were in the list. Based on a rise in failures to respond to simulated traffic situations, these intense "conversations" were judged to be significantly more distracting than "casual" conversations, which consisted of social chitchat with the experimenter (McKnight & McKnight, 1993). In a similar study, driving during an "easy" 2-minute dialog about current events impaired driving less than a complex "conversation" consisting of a 2-minute working memory task (i.e., sentence vs. nonsense). The complex conversation impaired driving in both firm and slippery road conditions (Briem & Hedman, 1995). Another study used a tracking task to simulate driving and found that simply listening and repeating words read by the experimenter did not significantly impair tracking errors. In other words, neither auditory input nor vocal output alone was sufficient to impair driving. However, a more demanding word-generation task caused cognitive distraction: When participants generated a new word that began with the last letter of a word read by the experimenter, driving was impaired (Strayer & Johnston, 2001).

Although these studies focused on conversational characteristics and made a distinction between simple and complex conversations, they did not attempt to replicate naturalistic, engaging, complex conversations that would actually take place outside the lab. Instead, they substituted working memory tasks.

More recently, Strayer and his associates at the University of Utah have used naturalistic dialog on current topics selected by participants to create "engaging" conversations.

In one study, using simulated traffic signals, the probability of a miss more than doubled when participants were actively engaged in a naturalistic conversation with an experimenter on a current event topic (e.g., the then-ongoing Clinton impeachment, the Salt Lake City Olympic Committee bribery case, or a topic of interest identified on the pre-experiment questionnaire). The second part of this study, using a high-fidelity driving simulator, showed that conversation significantly increased reaction time to unexpected events. The control group, who listened to books on tape or a radio broadcasts, showed no significant driving impairment (Strayer, Drews, Albert & Johnston, 2001).

A recent 4-part study by Strayer and his colleagues examined the hypothesis that engaging conversations caused a reduction in the processing of information falling directly into the driver's line of gaze, resulting in inattentional blindness which impaired driving performance. In this study, participants used a high-fidelity driving simulator to drive freeway scenarios with low- and high-density traffic and conversed with an experimenter on a topic of interest identified by the participant in the pre-experiment questionnaire. Conversation made reaction time significantly longer, particularly in high-density traffic. The experimenters noticed that participants attempted to compensate by increasing separation between themselves and the car ahead while conversing, but this strategy was ineffective. While participants had no accidents in low-density traffic, they were more likely to be involved in an accident while conversing in high-density traffic. All collisions were the result of the participant rear-ending the car in front of them during hands-free cell phone conversation. Both recognition and implicit memory were affected by cell phone conversation. Participants were less likely to create durable explicit memories (i.e., to be able to recognize objects as seen before) of billboards seen during conversations. The last part of the study was designed to explore the apparent reduction in visual attention by measuring the implicit perceptual memory for words presented at fixation during the pursuit-tracking task. The implicit memory paradigm provides an index of data-driven processing of visual information because the participant may remember without knowing—e.g., in a dot-clearing task, participants perceived "old" words already seen more quickly than new words. The study found that identification of old words was slower in the dual-task condition. So cell phone conversations may be presumed to reduce perceptual memory for items presented at fixation (Strayer, Drews & Johnston, 2003).

Summary of Driver Performance Studies

Early studies that focused on visual and biomechanical distraction, such as dialing and holding a hand-held phone, found—not surprisingly—that looking away from the road and taking the hands off the wheel impaired driving performance (Department of California Highway Patrol, 1987; Stein, Parseghian & Allen, 1987; Zwahlen, Adams & Schwartz, 1988; Brookhuis, deVries & deWaard, 1991; Serafin et al., 1993; Briem &

Hedman, 1995; Reed & Green, 1999). Based on these early studies, some place using a cell phone in the same "peripheral inteference" category as tuning a radio or applying makeup. Studies seen as supporting a peripheral interference hypothesis have led to the conclusion that if manual operation is eliminated drivers using hands-free models can compensate for any distraction (Brookhuis, deVries & deWaard, 1991; Green, Hoekstra & Williams, 1993). Recent laws banning hand-held cell phone use while driving are based on this conclusion.

The peripheral interference conclusion is not universal, however. Later studies using hands-free phones concentrated on the effects of the conversation itself. The later studies connect driving impairment—e.g., slower reaction time, failure to respond to roadway events, traveling outside the traffic lane, etc.—to the driver's failure to perceive roadway events (Brown et al., 1969; Recarte & Nunes, 2000; Parkes & Hooijmeijer, 2000; McCarley et al., 2001; Harbluk, Noy & Eiszenmann, 2002). Specifically, they established that drivers who are actively engaged in cell phone conversations experience reduced processing of information falling directly into the line of gaze. To a great extent, the studies eliminated simple listening and talking as the culprits by showing that active participation in a conversation is required in order to experience inattentional blindness (Strayer, Drews & Johnston, 2003). The studies also point to the central executive as the locus of the effect (Godthelp, Milgram & Blaauw, 1984; Green, 1994; Radeborg, Briem & Hedman, 1999).

The studies do not, however, identify *a priori* what kinds of conversations engage the attention in such a way as to cause inattentional blindness. Conversations that are “simple” vs. “complex,” “intense,” or “engaged” have only recently been addressed in studies at all. The few studies that do exist have either used artificial lab tasks (Brown et al., 1969; McKnight & McKnight, 1993; Alm & Nilsson, 1994; Briem & Hedman, 1995) or did not require complex cognitive decisions, computation, or longer-term memory retrieval (Strayer & Johnston, 2001; Strayer, Drews & Johnston, 2003). The use of memory tasks whose effects are well known helped to establish a connection between conversation and driving impairment, but did not help to generalize effects in the lab to effects on the road. The recent use of naturalistic conversation moves us closer to identifying what kinds of conversations impair driving. Even relatively simple social conversations showed a marked impairment effect, including inattentional blindness. So far, however, complex naturalistic conversations—the kind that really happen when drivers talk on their phones—have not really been studied.

The Current Study

The current study examines the distraction potential of varying levels of engagement in conversation. It extends existing research by placing the listening and talking activities within the context of naturalistic dialogs designed to be “simple” or “complex,” based on the level of cognition required. In particular, the study uses naturalistic conversation in order to observe the effects of a realistic “complex” dialogs rather than verbally presented working memory tests.

Method

Participants

Participants were 21 San Jose State University psychology students between the ages of 18 and 34. An additional 2 participants, whose data was not used, participated in pilot sessions. Participants were required to present valid drivers' licenses (to verify age) and have normal or corrected-to-normal vision. They received class credit, rather than financial payment, for participating in the experiment. See Appendix A for the participant screener.

Apparatus

The study uses a PC-based simulator: *Midtown Madness,* a game developed by Angel Studios (http://www.microsoft.com/games/midtown/). Participants drove using a LogiTech input device that included a steering wheel and foot pedals for accelerating and braking. Hands-free cell phone use was approximated using a microphone and intercom system between the room in which participants work and the control room. The rooms are separated by 1-way glass so that there is no visual contact between participants and the experimenter. An audio-visual record of the session was captured using 2 video cameras; the record included views of the monitor and the participant's face and all audio information. Equipment and laboratory space were provided by Interface Analysis Associates in Cupertino, CA.

Design

The study uses a within-subject factorial design. Driving as a single task, with no conversation, provided the control condition.

Driving Task

Using the demo mode of the *Midtown Madness* game, participants "drove" a defined route: the Loop around midtown Chicago. The route was easily explained and followed using the on-screen map and was large and complex enough to prevent a familiarity effect. The route included city and freeway driving, as well as several drivable piers and marinas that extend out into Lake Michigan from Lake Shore Drive (e.g., the Navy Pier and the water treatment plant, etc.). To provide route variations, participants drove in one direction then switched halfway through the session. Route presentation was counterbalanced (e.g., P_1 traveled clockwise, then counterclockwise; P_2 traveled counterclockwise, then clockwise, etc.). The driver's view is pictured below in Figure 2.

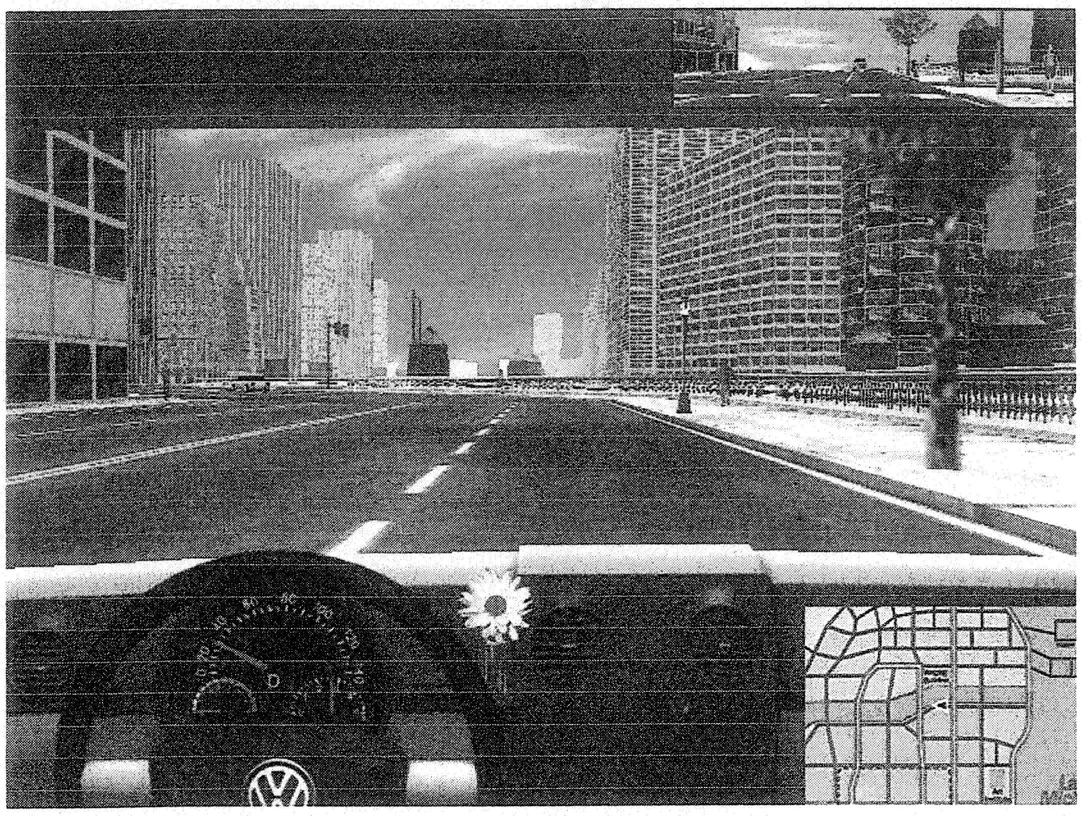

Figure 2. Driver's view showing the on-screen route map.

The 2 experimental factors and levels are shown in the table below.

		Factor B: Complexity	
		Simple	*Complex*
Factor A: Role	*Listening*	Listening + Simple	Listening + Complex
	Talking	Talking + Simple	Talking + Complex

Factor A: Conversational Role

Factor A (Role) had 2 levels, based on the participant's role in the dialog at a given time: the participant was either listening or talking (i.e., responding). Since these are well-understood activities, no further definition is provided here.

Factor B: Conversational Complexity

Factor B (Complexity) also had 2 levels based roughly on those used in by Boase, Hannigan and Porter (1988): simple Information dialogs (IDs) asking, for example, about favorite foods vs. more complex Negotiation Dialogs (Nds), for example having a holiday party booking altered by the travel agent. Operational definitions were based on different levels of demand which each placed on limited information processing resources—i.e., a single-channel bottleneck that exists for certain kinds of information (Paschler, 1998).

Simple conversation consisted of dialog that did not require much cognitive engagement. This condition was similar to the "engaged conversation" condition as defined by Strayer et al. (2001, 2003). The researcher introduced a topic while the participant listened. The talking portion required only acknowledgement or other short responses. Although it would be virtually impossible to converse without calling on short-term memory resources, a conversation defined as *simple* was designed to require central processing resources for an extremely short time. Simple conversations would necessarily be limited to reporting or recalling immediately available information—e.g.,"What are you doing now?"—"driving" or "What kind of car do you drive?—"a Honda Civic."

Complex conversation was designed to demand more cognitive engagement by occupying the central processor long enough to force the driving task to share access time with the conversational task. During complex conversation, participants formulated responses that involved computing, comparing/contrasting, deciding, interpreting, explaining (especially, explaining sequential information such as a process or route), or describing something at length or in detail.

Definitions for *simple* and *complex* were based on a preliminary investigation that examined real responses to presumed simple and complex prompts. During the investigation, prompts were read to 3 participants who fit the participant profile, but did not participate in the final study. Responses were recorded word-for-word and analyzed to see what kind of cognitive processing characterized each response. The pre-study suggested that it might be reasonable to use as a distinction direct reporting or recall (simple) vs. additional processing (complex). It also became clear that, although a prompt may be intended to elicit a certain kind of response, participants may not cooperate. Here is an example:

> Experimenter: "Do you get to the movies much?" (simple)
> Participant: "Yeah, I love movies…go all the time." (simple)
>
> Experimenter: "Well, what were the last couple of movies you saw?" (simple)
>
> Participant: "[Movie A] and [Movie B]." (simple)
>
> Experimenter: "Those are pretty different movies. What made you pick them?" (a complex prompt, inviting comparison/contrast and a long reply)
>
> Participant "Well, the actress had big, beautiful eyes." (This response, given quickly and without apparent introspection, would be scored as "simple.")

Although the prompts provided a template, the pre-study made it obvious that participant responses could be unexpected. Final simple vs. complex categorization was done during data gathering because of the nature of the conversations.

All conversations were naturalistic dialogs between the experimenter and the participant—i.e., conversations that might take place under real driving conditions on the road. The study did not use artificial "intelligence-test" tasks that required the participant to do mental arithmetic, word generation, or variations of the Baddeley Working Memory Span Test. Conversations were self-paced—i.e., the participant was not under explicit pressure to respond within a specified time. Self-pacing allowed participants to give primary attention to the driving task as they judged necessary, as they would do when driving on the road. See Appendix C for conversational topics and scripts used to prompt conversation during the study. The script contains 4 sets of mixed simple/complex topics, one set for each conversation: C_1, C_2, C_3, C_4. Presentation of topic sets was counterbalanced (e.g., P_1 got C_1, C_2, C_3, C_4; P_2 got C_2, C_3, C_4, C_1; P_3 got C_3, C_4, C_1, C_2).

Procedure

Each test session lasted approximately 1.5 hours, scheduled as shown below.

Minutes	Participant Activity
10	Arrival (greeting) and demographic survey
10	Practice

60	Factors interspersed:
	• Driving only (30 minutes)
	• Driving while conversing via cell phone (30 minutes)
	    • simple conversation (listening + talking)
	    • complex conversation (listening + talking)

10	Wrap-up and questionnaire
1 hour 30 min	**TOTAL SESSION TIME**

At the beginning of the session, participants read and signed a consent form (see Appendix B). Then the participant was shown how to use the simulator and given practice time to get familiar with the simulator and controls. The driving scenario provided by the simulator was of medium difficulty, as defined by traffic density, intersection density, scenery, and encounters with other vehicles. The scenario required the participants to start the car and drive city streets while monitoring and responding to other vehicles, traffic signals, and informational signs.

After practice, participants drove for a total of 60 minutes. During that time they also conversed with the experimenter via an open microphone to simulate hands-free cell phone use. Drivers were told to drive as they normally would and that they may pause or interrupt their interaction with the cell phone whenever they wish to attend to driving tasks. However, they were given no explicit instructions about how to divide their time between driving and other tasks. When not interacting with the cell phone, participants focused on driving only. In order to keep the conversation naturalistic and still vary the levels to create simple vs. complex conversation, topics initiated by the experimenter included both simple and complex dialogs (see Appendix C). The session ended with a brief survey that asked for perceptions about performance and difficulty of the tasks (see Appendix D).

Dependent Measures

Driving performance was measured based on the following objective measures that reflect response planning and adjustments made in order to maintain vehicle control, guidance, and preservation of a safety envelope:

- *near misses (frequency)*—measured by the number of times the participant avoids a collision with an obstacle or vehicle by taking drastic action
- *collisions (frequency)*—measured by the number of times the car hits an obstacle or vehicle

- *failure to respond (frequency)*—measured by the number of signals, signs, and events to which the driver fails to respond
- *lane deviations (frequency and duration)*—measured by the number of times and how long the driver allows the car to travel outside the lane of traffic (e.g., into the oncoming lane or onto the shoulder of the road)
- *exceeding the speed limit (frequency and duration)*—measured by the number of times and for how long speed is over the current speed limit by at least 5 MPH

Subjective data was measured by perceived-distraction questions (5-point scale) and comments in the exit questionnaire.

Hypotheses

The 2-factor design, with a single-task control, lent itself to 5 hypotheses, which are explained below.

1. First, the dual-task condition (i.e., using a cell phone) was expected impair driving performance, as compared to driving as a single task.
2. In addition, cell phone conversation was expected to impair driving performance in relation to the driver's level of engagement in the conversation. For Factor A (Role), talking was expected to impair driving more than listening.
3. For Factor B (Complexity), complex conversations were expected to impair driving more than simple conversations.

4. Talking during complex conversations was expected to cause the greatest driving impairment; listening during simple conversations, the least.
5. The subjective data (from a post-session survey) was expected to show that participants dissociated conversation and driving impairment by stating that conversing on a cell phone did not affect their ability to drive safely.

Data Scoring

The process of data gathering involved watching the videotapes while simultaneously logging events and conditions using the *Activity Catalog Tool (ACT)* application to obtain data for statistical analysis. Logging involved keying in events (e.g., collisions, lane deviations, etc.) and conditions (e.g., listening, talking, driving only) and categorizing/logging complexity (e.g., simple vs. complex). All data gathering was done by the author, who practiced before each session and completed all data gathering within 5 days.

Analysis

To establish whether simulated hands-free cell phone conversation impaired driving, within-subject Analyses of Variance (ANOVAs) were run using the SPSS statistical package (version 10.0 for Windows®). For each dependent measure, a single-factor ANOVA (1 x 3) was used to analyze main effects for A and B; and a two-factor (2 x 2) ANOVA with replications was used to analyze A x B interactions. To analyze single- vs. dual-task effects, *t* tests were run on SPSS. An alpha level of .05 was used for all statistical tests.

Results

This section reports both objective driving performance data and subjective data from the post-session survey.

Objective Data

Table 1 summarizes errors per minute and error durations for the 7 dependent measures. Note that while all measures provided error frequency data, only lane deviation and speeding also provided continuous data. The Totals column allows comparison of single- to dual-task error rates. Dual-task data includes separate error rates for Role (A) and Complexity (B), and A x B interactions.

Table 1.

Errors Per Minute and Duration for the Dependent Measures

Measure	Dual Task Errors Per Minute			Totals
	Factor A: Role	Factor B: Complexity		
Near Miss (frequency)		B: Simple	B: Complex	
	A: Listen	0.37	0.53	0.45
	A: Talk	0.37	0.78	0.57
		0.37	0.65	
			Dual Task	0.51
			Single Task	0.31
Collision (frequency)		B: Simple	B: Complex	
	A: Listen	4.02	3.40	3.71
	A: Talk	3.61	3.49	3.55
		3.81	3.44	
			Dual Task	3.63
			Single Task	2.58
Fail to Respond (frequency)		B: Simple	B: Complex	
	A: Listen	2.53	1.65	2.09
	A: Talk	2.35	3.80	3.07
		2.44	2.72	
			Dual Task	2.58
			Single Task	2.17
Lane Deviation (frequency)		B: Simple	B: Complex	
	A: Listen	7.47	9.75	8.61 *
	A: Talk	10.77	11.93	11.35 *
		9.12	10.84	
			Dual Task	9.98
			Single Task	7.86
Speeding (frequency)		B: Simple	B: Complex	
	A: Listen	6.66	6.25	6.45
	A: Talk	8.47	9.34	8.90
		7.56	7.79	
			Dual Task	7.67
			Single Task	8.09

Table 1. (continued)

Errors Per Minute and Duration for the Dependent Measures

Measure	Dual Task Error Duration Means			Total Means
	Factor A: Role	Factor B: Complexity		
Lane Deviation (duration)		B: Simple	B: Complex	
	A: Listen	1.6 sec	2.0 sec	1.80 sec *
	A: Talk	2.2 sec	2.5 sec	2.35 sec *
		1.90 sec	2.25 sec	
			Dual Task	2.07 sec *
			Single Task	2.70 sec *
Speeding (duration)		B: Simple	B: Complex	
	A: Listen	4.1 sec	5.0 sec	4.55 sec *
	A: Talk	5.9 sec	7.8 sec	6.85 sec *
		5.0 sec	6.40 sec	
			Dual Task	5.70 sec *
			Single Task	13.6 sec *

Note. Totals are grouped by shaded areas: black for single- and dual-task totals; gray for Role and Complexity totals; no shading for A x B interaction totals. * = This value has statistical significance.

Table 2 below presents the results of tests for statistical significance for observed effects. F and t statistics with significance are marked with asterisks (*).

Table 2.

Analyses of Variance (ANOVAs)

Source	*df*	*F*	*p*
		Within subjects	
Near Miss Frequency			
Single Task (Control)	20	-1.934 (*t*)	.067
Role (A)	2	1.103	.342
Complexity (B)	2	1.660	.203
A X B	1	.187	.670
A X B within-group error	20	(.004)	
Collision Frequency			
Single Task (Control)	20	-1.909 (*t*)	.071
Role (A)	2	1.421	.253
Complexity (B)	2	1.744	.188
A X B	1	.068	.797
A X B within-group error	20	(.043)	
Fail to Respond Frequency			
Single Task (Control)	20	-1.437 (*t*)	.166
Role (A)	2	2.495	.095
Complexity (B)	2	1.329	.276
A X B	1	3.378	.081
A X B within-group error	20	(.019)	
Lane Deviation Frequency			
Single Task (Control)	20	-1.820 (*t*)	.084
Role (A)	2	4.059 *	.025
Complexity (B)	2	2.141	.131
A X B—Role	1	7.202 *	.014
A X B	1	.256	.618
A X B within-group error	20	(.058)	
Speeding Frequency			
Single Task (Control)	20	-0.107 (*t*)	.916
Role (A)	2	2.587	.088
Complexity (B)	2	.131	.878
A X B—Role	1	7.18 *	.014
A X B	1	.699	.413
A X B within-group error	20	(.028)	

Table 2. (continued)

Analyses of Variance (ANOVAs)

Source	*df*	*F*	*p*
		Within subjects	
Lane Deviation Duration			
Single Task (Control)	20	-5.192 (*t*) *	.000
Role (A)	2	3.923 *	.028
Complexity (B)	2	2.156	.129
A X B—Role	1	6.28 *	.021
A X B	1	.093	.764
A X B within-group error	20	(1.157)	
Speeding Duration			
Single Task (Control)	20	-3.198 (*t*) *	.005
Role (A)	2	3.502 *	.04
Complexity (B)	2	.956	.393
A X B	1	0.708	.41
A X B within-group error	20	(6.073)	

Note. All statistical analysis used alpha=.05. Values enclosed in parentheses represent mean square errors. * = This value has statistical significance.

As Table 2 shows, single- vs. dual-task effects showed statistical significance only for lane deviation duration and speeding duration; effects for frequency measures were prevented from achieving statistical significance by alpha levels above 5%: critical value for $t(20) = \pm\, 0.687$, $p<.05$, two-tailed. Role showed a significant effect only for lane deviation frequency, lane deviation duration, and speeding duration. Role also showed the only significance within interaction effects, for lane deviation frequency and duration and speeding frequency. The statistical analysis demonstrated that Role had a slight effect on driving performance which interacts with Complexity. There was no evidence that Complexity alone had an effect on driving performance.

Single- vs. Dual-Task Results

Single- vs. dual-task effects were statistically significant only for lane deviation and speeding durations, as shown in Table 2. Figure 3 below shows that dual-task performance was worse across 4 of the 5 frequency measures: errors per minute rose for near misses (66%), collisions (46%), failures to respond (18%), and lane deviations (26%). Durations dropped during the dual task. For lane deviation, where a rise in frequency is paired with a drop in duration, participants may have cycled in and out of the error condition more quickly during the dual task. For speeding, where both frequency and duration dropped, participants apparently slowed down during phone conversation. Although without statistical significance, the rise in frequency seems to confirm expectations based on existing research—i.e., that phone conversation impairs driving.

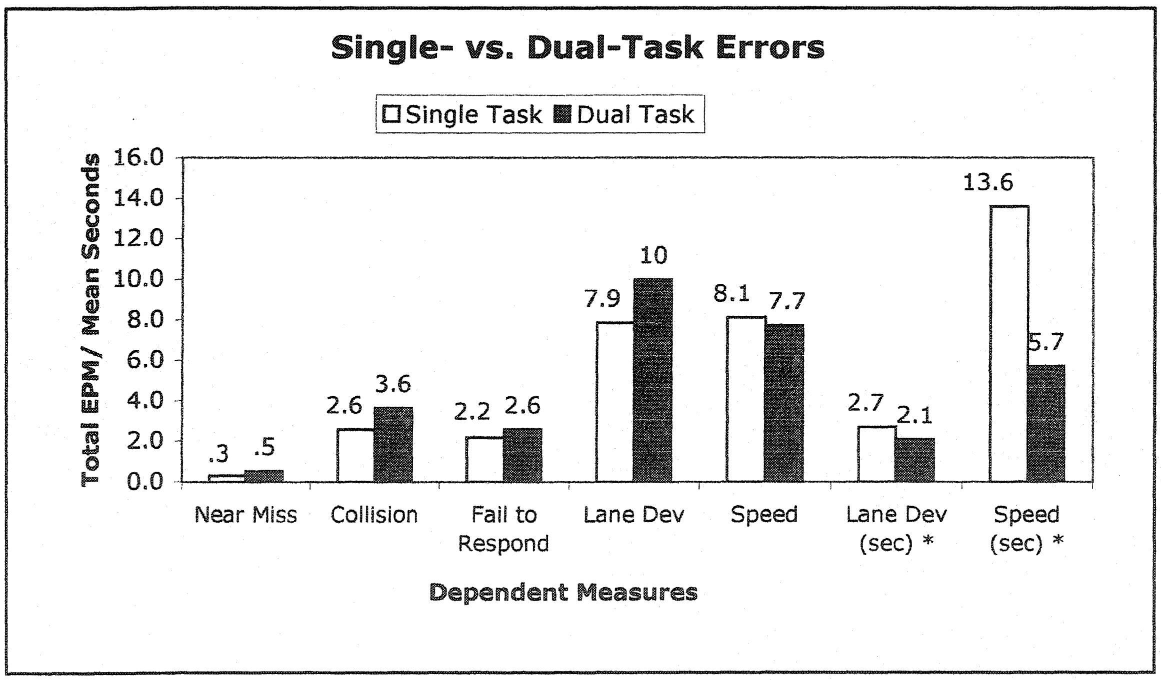

Figure 3. Error means for single- and dual-task conditions.

Main Effect for Role (A): Listening vs. Talking

The effect of Role (listening vs. talking) was significant only for lane deviation frequency, lane deviation duration, and speeding duration. Figure 4 shows that driving performance was consistently poorer while talking than while listening across all measures except collisions. While participants talked, errors and durations rose for near misses (20%), failures to respond (47%), lane deviations (32% for frequency and 33% for duration), and speeding (36% for frequency and 50% for duration). Performance was poorer while talking than while driving as a single task for all 5 frequency measures: Errors per minute rose for near misses (100%), collisions (38%), failures to respond (40%), lane deviation (44%) and speeding (9%). Listening showed no consistent effect on driving performance. It either slightly impaired or slightly improved performance, as compared with driving as a single task. Consistent with single- vs. dual-task results, error durations were shorter for both listening and talking than for driving as a single task.

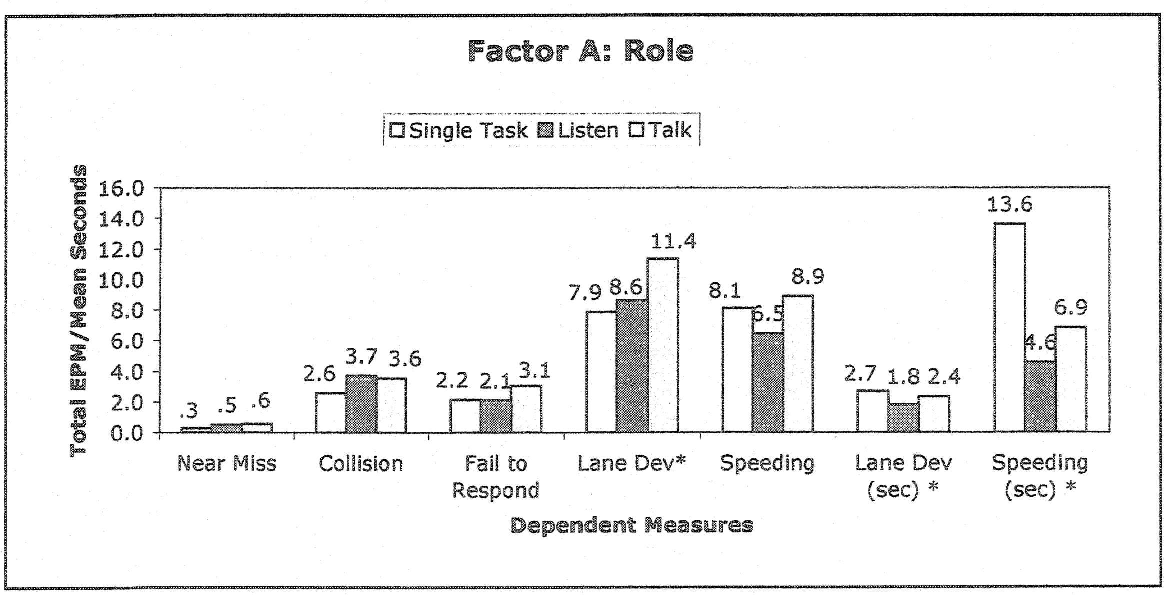

Figure 4. Main effect of Role (A) on driving errors.

Figure 5 represents trends for frequency and duration collapsed across dependent measures. In general, talking resulted in poorer performance than either listening or driving. Both listening and talking resulted in much shorter error durations than driving as a single task.

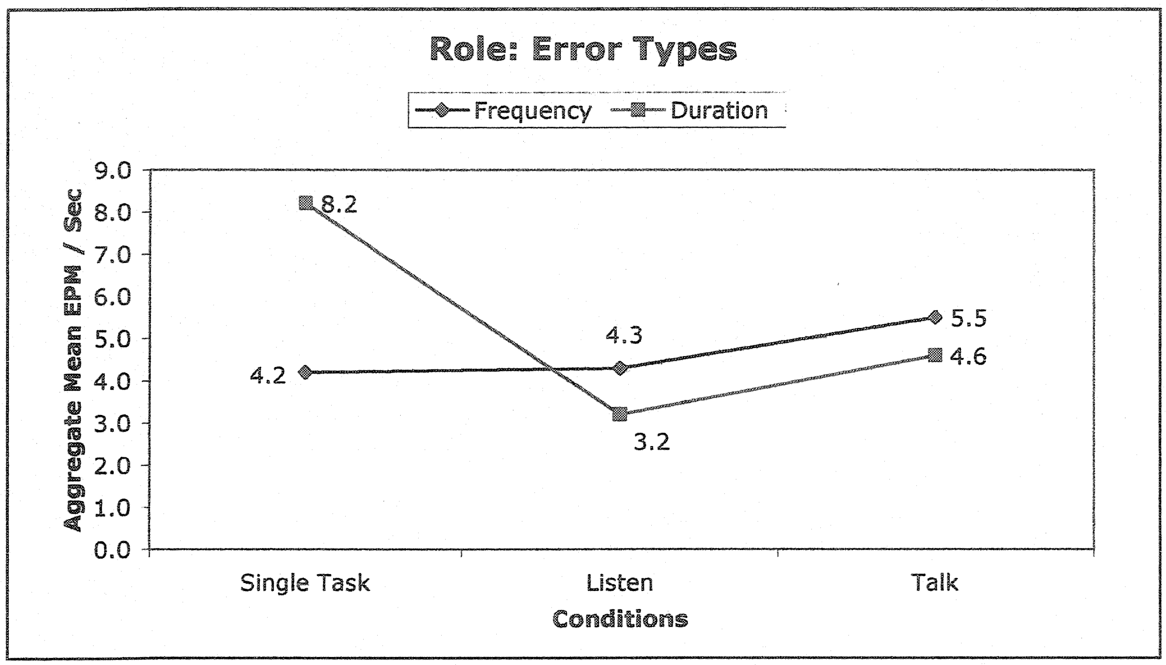

Figure 5. Effects of Role on frequency and duration of driving errors.

Main Effect for Conversation Complexity (B)

As shown in Table 2, Complexity failed to show statistical significance for any of the dependent measures. Figure 6 below shows that driving performance was consistently poorer during complex conversation than during simple conversation across all measures except collisions. During complex conversations, errors and durations rose for near misses (75%), failures to respond (12%), lane deviations (18% for frequency and 21% for duration), and speeding (2% for frequency and 28% for duration). Performance was poorer during complex conversations than while driving as a single task for 4 of the

5 frequency measures: Errors per minute rose for near misses (133%), collisions (30%), failures to respond (22%), and lane deviations (36%). Simple conversation showed no consistent effect on driving performance. It either slightly impaired or slightly improved performance, as compared with driving as a single task. Consistent with single- vs. dual-task results, error durations were shorter for both simple and complex conversation than for driving as a single task.

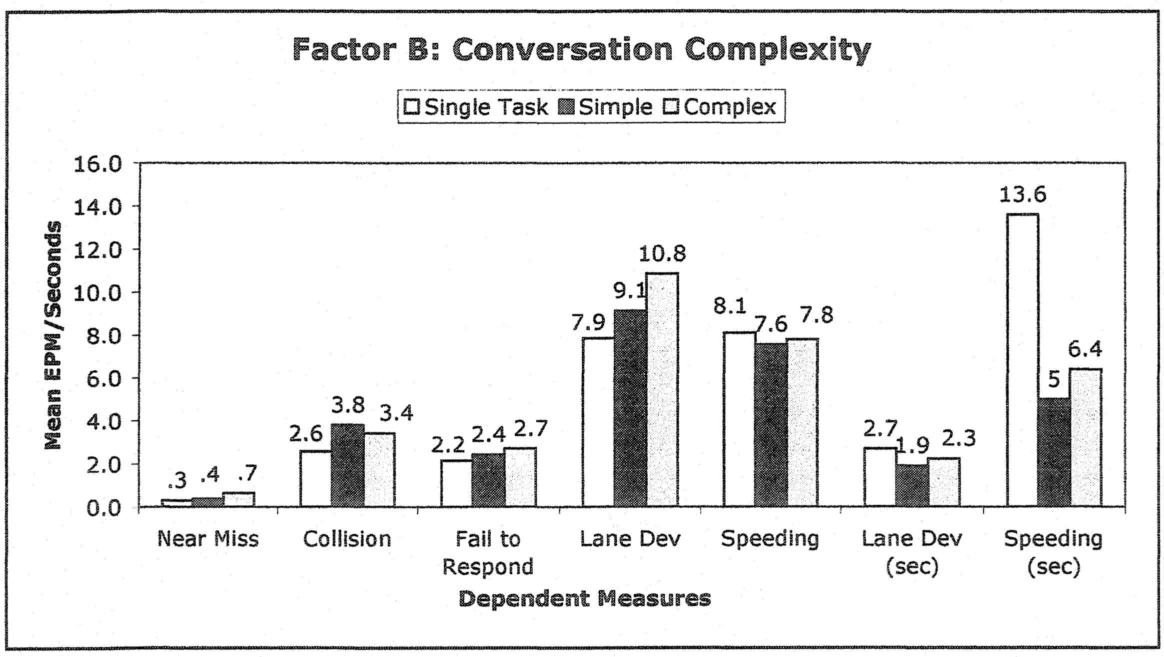

Figure 6. Main effect of Complexity (B).

Interactions Between Role and Complexity

Interactions between Role and Complexity did not show statistical significance for any of the dependent measures. Figure 7 shows 2 trends that can be seen most clearly for lane deviation and speeding, and to some extent in near misses and failures to respond. First, talking resulted in poorer performance than listening during both simple and complex conversations. Second, talking during complex conversations resulted in the poorest performance of any of the conditions.

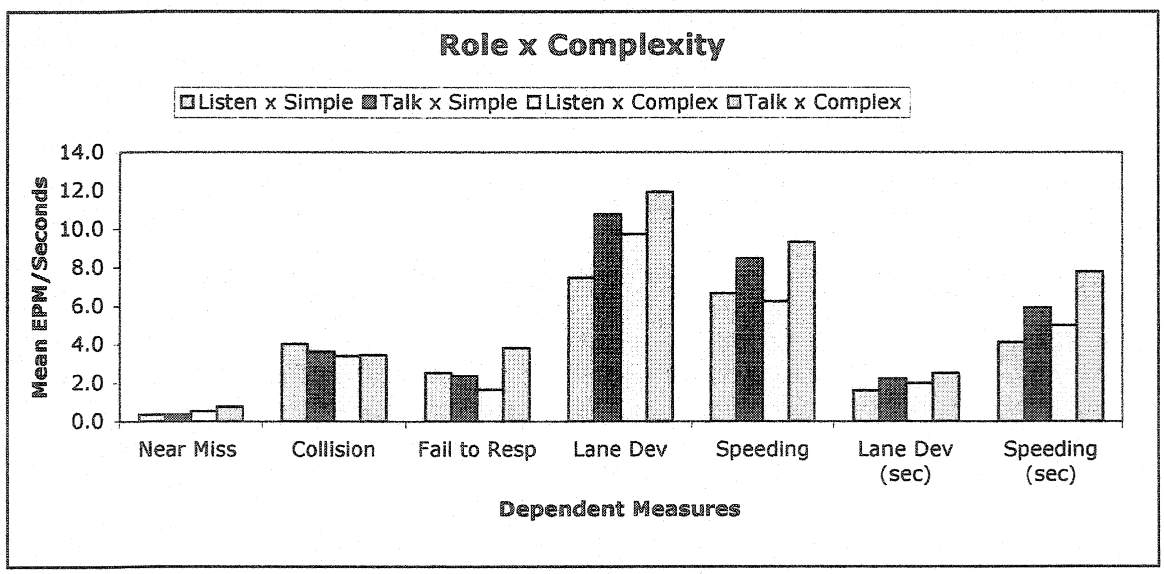

Figure 7. Role x Complexity interactions.

Figures 8 and 9 below plot the effects of Role across the 2 levels of Complexity for all dependent measures. In each figure, the lines are virtually parallel, reflecting the lack of significant interaction.

Figure 8 plots the effects of Role x Complexity for error frequency. The trend lines show that Complexity only has an effect for the talking condition of Role. Talking vs. listening resulted in a slightly larger difference in errors per minute during complex conversations (1.6) than during simple conversations (.9).

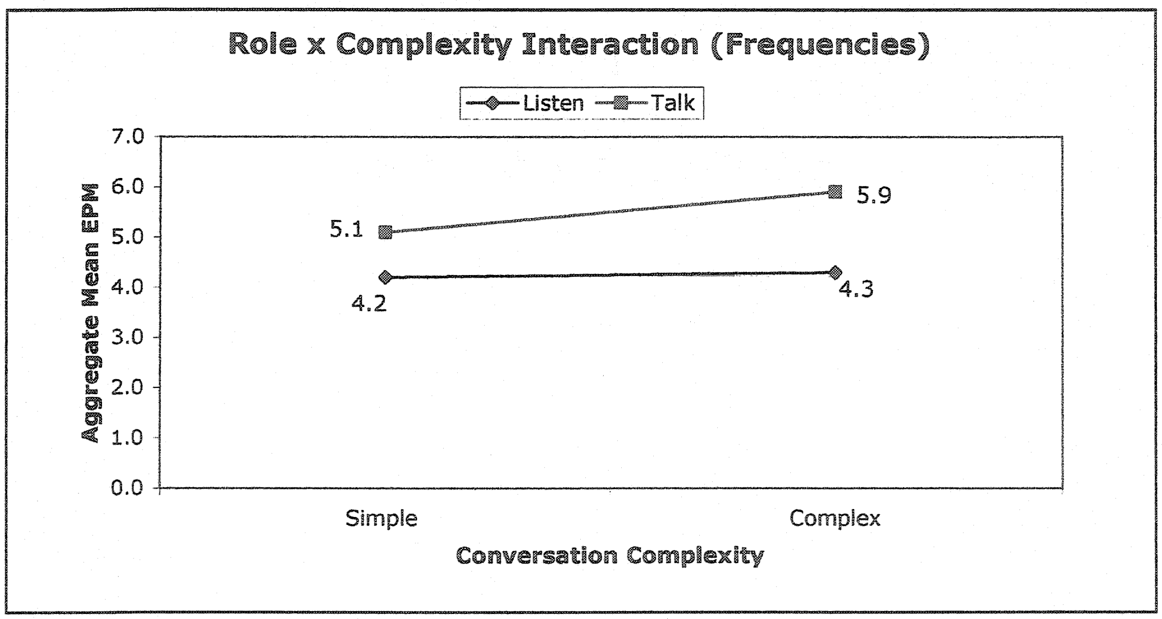

Figure 8. Role x Complexity interaction for error frequencies.

Figure 9 below shows the same trend for error durations. Talking vs. listening resulted in a slightly larger difference in errors per minute during complex conversations (1.7) than during simple conversations (1.2).

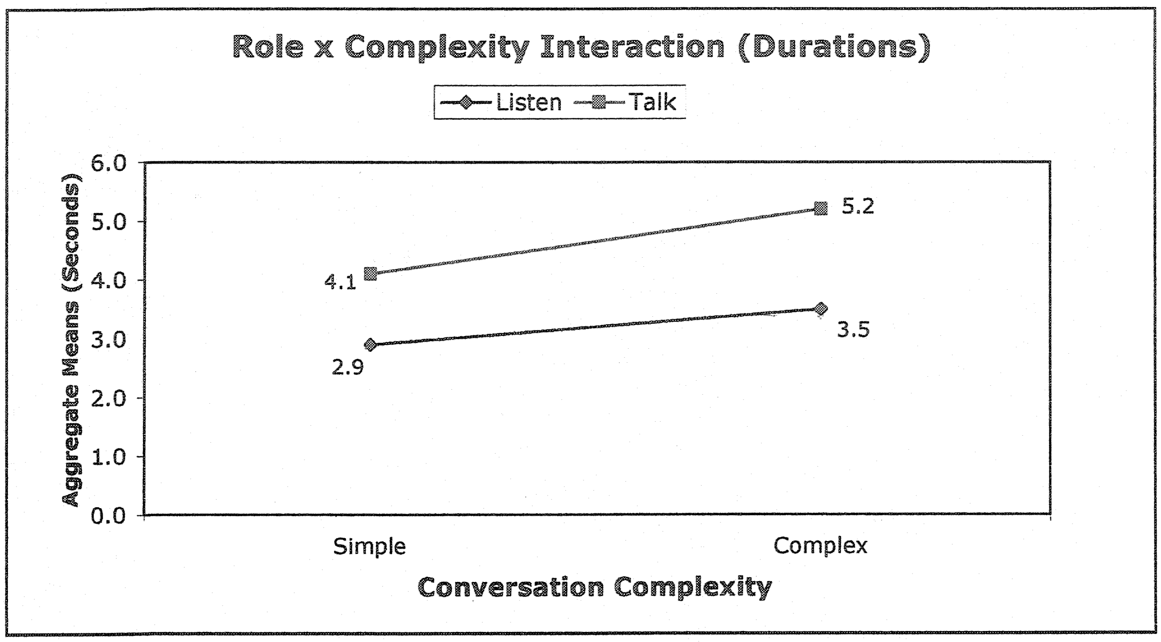

Figure 9. Role x Complexity interaction for error durations.

Ranking

Another way to represent differences is to force-rank conditions using an ordinal scale. Overall rankings allow comparison of results without statistical significance. In Table 3 below, experimental conditions are ranked across all dependent measures based on mean error totals. The ranking results upheld the results of the main effects and interactions discussed above. For Role, listening showed better performance than talking. For Complexity, simple conversation showed better performance than complex. This result was reinforced in the Role x Complexity rankings, where talking again showed the worst performance, particularly during complex conversations.

Table 3.

Ranking Across All Conditions

Dependent Measures	Conditions								
	Single Task	Dual Task: Role (A)		Dual Task: Complexity (B)		Dual Task: A x B Interactions			
	D	L	T	S	C	LS	LC	TS	TC
Near Miss	1	2	3	1	2	2	3	1	4
Collision	1	3	2	2	1	4	2	3	1
Failure to Respond	1	2	3	1	2	3	1	2	4
Lane Deviation	1	2	3	1	2	1	3	2	4
Speeding	2	1	3	1	2	2	1	3	4
Lane Deviation (duration)	3	1	2	1	2	1	2	3	4
Speeding (duration)	3	1	2	1	2	1	2	3	4
Mean	1.7	1.7	2.6	1.1	1.9	2	2	2.4	3.6
RANK	**1**	**1**	**3**	**1**	**2**	**1**	**1**	**3**	**4**

Key:

D = Drive (single task)
L = Listen (A)
T = Talk (A)
S = Simple (B)
C = Complex (B)

LS = Listen (A) x Simple (B)
LC = Listen (A) x Complex (B)
TS = Talk (A) x Simple (B)
TC = Talk (A) x Complex (B)

1 = best performance

Subjective Data

Each participant completed a post-session survey designed to check perceptions about the driving experience (see Appendix D). The survey focused on how easy or difficult it was to safely drive the simulator while driving only, while driving and listening, and while driving and talking. Exactly half of the participants rated their driving performance during the session as "very poor" or "somewhat poor." Unfortunately, the questionnaire did not ask for a reason, so we cannot assume an association with distraction. Others factors, including the difficulty of driving a simulator, may have contributed to the perception.

Perceived Difficulty and Distraction

Figure 10 below represents responses to questions 2, 3, and 4, which asked "...how difficult was it to drive safely...while [driving only / talking / listening]?" Figure 11 represents total responses for similar questions 8, 9, and 10, which asked "...how distracting was it to drive...while [driving only / talking / listening]?" Participants answered using 5-point scales of perceived level of difficulty (very easy to very difficult) or distraction (very low to very high), respectively.

As Figures 10 and 11 show, participants were aware of the distraction potential of conversing on a phone while driving. They also seemed to be aware that talking and listening might impair driving. Based on the response distribution across categories, participants felt that listening had an average-to-high effect on driving, but talking might have a greater effect. Talking got more responses in the "very difficult" and "very high distraction" categories than listening.

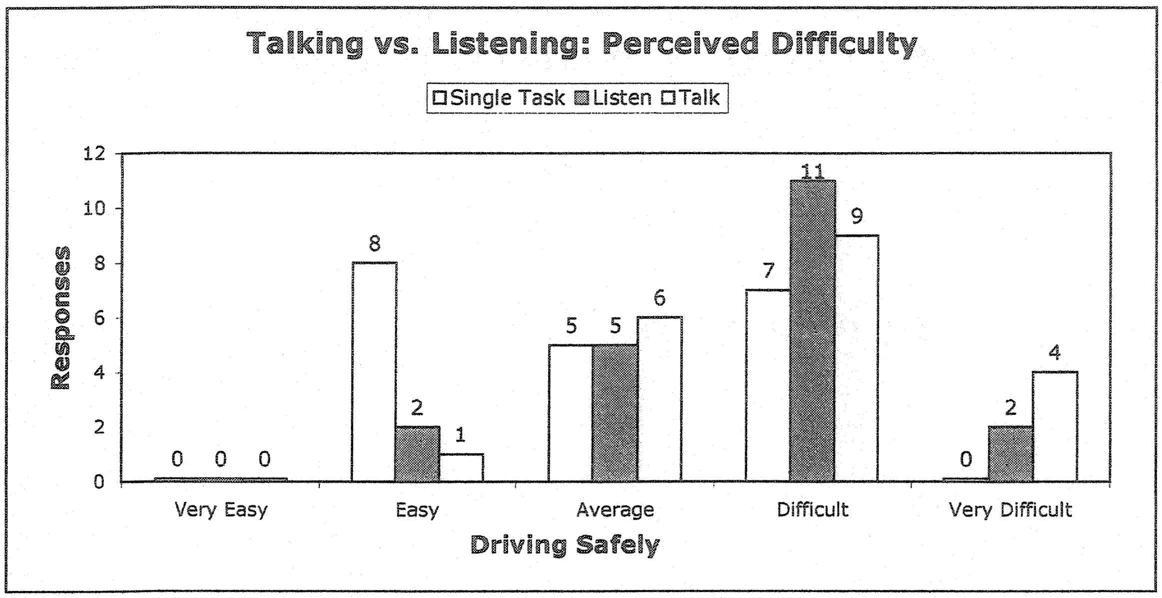

Figure 10. Perceived difficulty in driving.

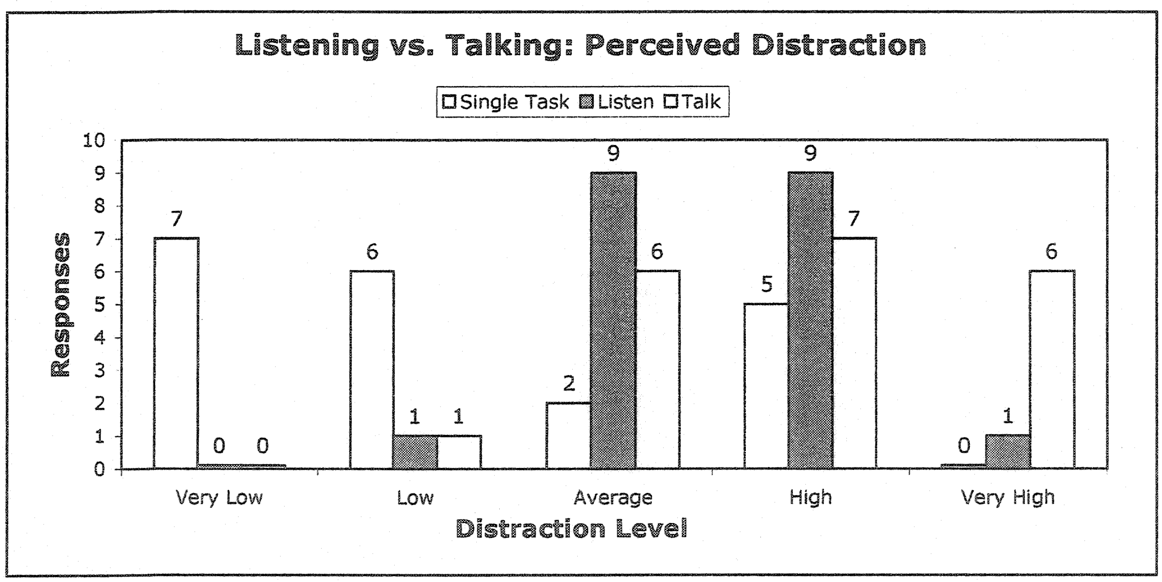

Figure 11. Perceived distraction.

Figure 12 below compares driving performance based on objective measures with participants' perceptions of how difficult it was to drive safely and without distractions. Error Frequency and Error Duration are aggregate means across participants and dependent measures. The lines represent error rate trends discussed earlier: Listening produced fewer errors than talking.

The Perceived Difficulty/Distraction trend line uses weighted values to represent perceptions about driving, listening, and talking in a way that allows comparison with performance results. Values were calculated by multiplying the number of responses at each level on the 5-point scale by a number that reflects relative perceived difficulty: i.e., 1=very easy/very low distraction through 5=very difficult/very high distraction. In the resulting values, lower numbers indicate better-perceived performance in the subjective data (e.g., easy to drive safely, low distraction), just as fewer errors indicate better performance in the objective data. Finally, since these weighted values only have meaning relative to each other and to the error means for performance data, the values were divided by 5 to bring them within the same numeric range as the aggregate error means.

In Figure 12, we see evidence of dissociation between perception and performance. Participants said that both talking and listening were distracting and rated talking slightly more distracting than listening. However, listening vs. talking performance showed greater differences than listening vs. talking ratings.

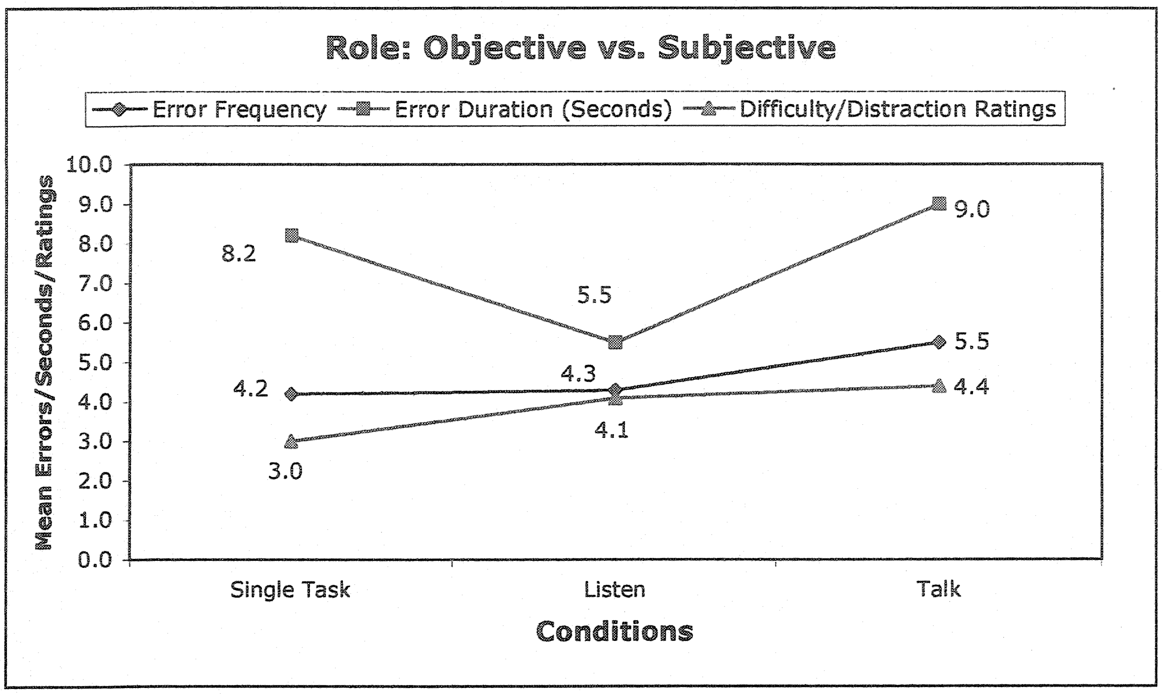

Figure 12. Objective and subjective data.

Distracting Conversational Elements

Participants were also asked to identify conversations, conversation elements, or other factors that caused distraction and affected their driving during the session. In response to 3 questions asking whether particular conversations or conversational elements affected their driving negatively, 66% responded "Yes." Tables 4 and 5 below show that participants often used very specific language to point out the perceived causes of distraction: listening, talking ("talking for a long time," "long-term answer," "describing," "explaining," "express my opinion"), thinking ("thought-provoking conversation", "think hard," "visualize,"), and remembering ("come up with things from memory," "in-depth memory," "from a long time ago"). When asked to point out particular conversations that were difficult to engage in while driving, participants focused mostly on topics they found engaging or interesting, such as sports, cars, web sites, and war (this from a participant whose brother was serving in Iraq). Figures 10, 11, and 12 indicate that participants saw both listening and talking as potentially distracting, but seemed to perceive listening as being slightly more distracting. However, a summary of the words participants used to describe distracting conversational elements revealed a contradiction. The words used indicated that listening was not nearly as distracting as talking or response planning (i.e., complex conversation). In Table 4 below, note that the rows with the highest count—80% of the total—describe talking or response-planning activities. At 12%, listening comes in a distant second.

Table 4.

Distracting Conversational Elements

Count	Words used to describe distracting conversational elements
23	Talk, answer, explain describe
18	Think, thought-provoking, remember, in-depth memory, thinking back
6	Listen
3	Interested
1	Visualize
51	TOTAL

Based on subjective data, participants did not dissociate phone use with impaired driving performance. In general, they associated overall phone use with impaired driving performance, which matches the performance data. They understood that listening, talking, and thinking while driving can distract them and impair driving performance. However, participants' perceptions about the relative distraction potential of listening and talking did not match the performance data.

Table 5.

Participant Comments About Distraction

Question 5A:	Were there any *aspects of particular conversations* you had during this session that made driving safely more difficult?
Responses:	17 of 20 (85%) responded *Yes*
Comments:	All 17 comments indicated an awareness of distraction caused by listening, talking, formulating answers to questions, long-term memory demands, visualization, or being actively engaged and interested in the conversation. • When we **talked** about the war in Iraq vs. Vietnam War I had to **think** about some of my **answers**. That made it hard to concentrate on the road and where I was going. • Making me **think** about a question and come up with an **answer** made it difficult to drive. • When I had to **think** about a question. Instead of giving short-term answer I had to give a **long-term answer**. • When questions were asked that I had to think more to give an **answer**. • **Describing** details. **Answering** questions. • **Listening** and really paying attention to be able to give **answers**. • If I was like **describing** something to someone or **talking** about things we had in common or liked. • When [I was **listening** to you talk] about the web site. It becomes more difficult to drive. • Actually when **talking** of something that had me **interested** I was more immersed into the conversation than actually driving. • Trying to **visualize** the web site. Trying to come up with things from **memory**. • More difficult when I was **explaining** things, instead of yes or no answers. • When I had to **think** to **answer** a question. • **Thinking** about random things to **answer** the question. Thinking back on what happened or recently happened. • Whenever I had to **think hard** about something or ...**describe** something. • When I had to **think** of something from my personal life; something that I wasn't too sure of. This would distract my attention off the road. • When I had to try and **remember** the names of things. • When asked questions that required **in-depth memory**.

Table 5. (continued)

Participant Comments About Distraction

Question 6:	*What, if anything*, do you feel affected your driving during the session?
Responses:	Half of the 18 responses focused on distractions caused by conversation. The wording is interesting because it was often specific: 2 mentioned "conversation," 4 mentioned "listening," and 6 mentioned "talking." • Thought-provoking **conversation.** • **Talking** and **listening** were a distraction. Trying to keep in my lane while driving at a certain speed limit. Brake time. • ...the phone (**talking** and **listening**). • Trying to focus on the road and **listen**. • **Listening** to the person on the other line. • When I was **talking**. • While driving, I found it hard to focus while **talking** for a long time. • **Talking** to someone else. • **Talking** and **conversating** [sic].
Question 7:	Does *conversing while driving* have a negative effect on your driving performance?
Responses:	14 of 20 (70%) said *Yes*
Question 8A:	Were some of the *conversations* we had today more difficult to engage in while driving than others?
Responses:	9 of 11 (45%) said *Yes*
Comments:	The participants pointed out engaging or interesting conversations, having to explain, or having to recall from long-term memory. • Yes, also the **war** in Iraq vs. Vietnam War. [Participant's brother was serving in Iraq.] • Like asking out of the blue questions about **cars** and **sports** or Vietnam **War**; basically, **thinking** questions. • The topics where I wasn't too sure of or were from a **long time ago**. Sports topics where I had to **think**. Web site that I had **interest** in. • What **sports** teams are underrated. • The **web site** conversation. The conversation about **sports** (I think I continually became lost [driving] during that conversation.) • The ones where I would have to **explain** anything. • When I was asked to express my **opinion**. • **Web site**. Couldn't remember car type. Couldn't **recall** facts.

Summary of Results

Objective data showed that driving performance was generally impaired while talking, especially during complex conversations. Subjective data indicated that participants realized that phone conversation impairs driving, but were largely unaware that talking would impair their driving performance more than listening. Interestingly, their descriptions of distracting conversational elements suggested an awareness that talking, responding, thinking may have impaired their driving performance during the session more than listening.

Discussion

A lack of statistical significance across measures did not allow rejection of any of the null hypotheses. However, the data did show some emerging trends.

Hypothesis: Phone Conversation Will Impair Driving

The first hypothesis was based on the assumption that, under dual-task conditions, driving performance would be impaired by conversational tasks that placed heavy demands on a single-channel response-planning mechanism. Pairing an intermittent LTM task (conversation over a simulated hands-free phone) with a continuous task requiring manual response (driving), should favor the memory task and delay the reaction task (Pashler, 1998). In the dual-task condition, driving performance did show impairment across most dependent measures. The effect appears to replicate existing research findings that phone conversation impairs driving.

Hypothesis: Talking Will Impair Driving More than Listening

Role (A) showed statistical significance for only 3 of the 7 measures, which did not allow rejection of the null hypothesis. In general, however, talking resulted in poor performance than both listening and driving as a single task.

Listening

As continuous tasks with intermittent response demands, conversing and driving required that participants process information arriving on more than one channel at a time with the goal of monitoring the contents of both channels to detect "targets" which required response. Based on attention theory, people are efficient at bimodal monitoring tasks, like driving and listening. Such tasks can be done in parallel, are relatively free of capacity limits, and become more efficient with practice (Pashler, 1998). Realistically, we must assume that some response planning may have occurred while participants were listening. But for highly practiced tasks, adroit scheduling of access time may be sufficient to handle the demand. For these participants—experienced younger drivers—both driving and conversing were well practiced enough to be highly routine. As expected based on perceptual resource sharing theory, listening showed little effect on driving performance.

Participants perceived listening and talking as having an average-to-very-high distraction level, making it difficult to drive safely. Based on this data, it is reasonable to assume that participants had a heightened awareness of potential distractors that may have caused them to drive more slowly and carefully while listening and talking. This reasoning also argues that when participants were aware of a potential distractor they were not, in fact, distracted. If participants were able to consciously allocate resources (i.e., selective attention) while listening in a way that kept errors low, they did not meet a defining criterion for distraction: " ...when attention is redirected or captured without any voluntary choice having taken place" (Pashler, 1998, p. 3).

Talking

Talking appears to rely on the central processing resources that handle a single response at a time and handle overload by queuing, which creates a response planning "bottleneck." For highly practiced tasks, the response selection operation may be so lacking in salience that people hardly notice it, particularly when it takes the form of a brief delay that does not seem to seriously disrupt performance (Pashler, 1998).

However, performance seems to be disrupted when people try to select and produce two independent externally paced (i.e., speeded) responses at the same time (Pashler, 1998). That driving is often externally paced is obvious. But a cell phone conversation may also be externally paced. Unless the participant signaled a need to interrupt or end the conversation (the signal itself would be a planned response), the conversational pace does not adapt itself to the needs of the driving task.

Error rates for talking, especially during complex conversations, seem to indicate that talking required more response planning than listening, leaving participants less opportunity to plan driving responses. In addition, participants did not seem to notice how distracting talking was, as compared to listening. Although without statistical significance, results showed that driving while talking consistently resulted in poorer performance than performance while listening or while driving alone, which suggests that participants may have been distracted.

Even without statistical significance, the trends shown in Role results generally supported attention theories on perceptual resource sharing (i.e., while listening) and the existence of a central executive "bottleneck" for response planning (i.e., while talking).

Hypothesis: Increased Complexity Will Impair Driving

Complexity (B) showed no statistical significance, which did not allow rejection of the null hypothesis. Although without statistical significance, there was a trend in the expected direction: complex conversation tended to impair driving more than simple conversation.

The lack of significance in the main effect may have been partially due to the fact that the 2 levels—simple and complex—were not discrete categories, like listening and talking. The Complexity factor attempted to demonstrate the effects of conversations that differ in the levels of demands made on the presumed response-planning bottleneck. "Complex" conversations were designed to deny planning resources to the driving task longer than "simple" conversations, by requiring participants to retrieve information from LTM, make judgments, or plan responses (Pashler, 1998). The differences between simple and complex conditions lie along a continuum of response-planning access time required. If the exemplars used in this study were not far enough apart on the continuum, an observed effect would be too small to show statistical significance.

Hypothesis: Role x Complexity Interactions Will Affect Driving

Role (A) x Complexity (B) interactions showed no statistically significant effect, so the null hypothesis could not be rejected. However, there was a slight trend suggesting that the effects of Complexity may differ across the levels of Role: Complex conversations negatively effected talking but not listening. Complex, response-intensive conversations resulted in the greatest number of driving errors that are known to characterize both driver inattention (i.e., distraction) and cell phone use: rear-end collisions, failures to respond to traffic signals or events, lane deviations, and, to a lesser extent, speeding (Goodman et al., 1997; Green, 1994; Stutts et al., 2003).

Hypothesis: Participants Will Dissociate Conversation and Driving Impairment

Subjective data do not support rejection of the null hypothesis as it was stated. Participants did not dissociate conversation and driving impairment. Instead, they reported that they found both listening and talking distracting, but were not aware that talking impaired driving more than listening or that conversation complexity magnified the effect of talking.

Implications

The study provided insight into conversational elements that may impair driving during cell phone use and insight into why this problem is not yet fully understood. The results suggested that cell phone use may not impair driving under all circumstances. The precise effect of phone conversation was difficult to pinpoint for several reasons. In the dual-task condition, elements that did not seem to distract from driving (e.g., listening) were continuously interspersed with conditions that seemed to be distracting (e.g., talking during conversations that require complex response planning). When present, response planning may not have been salient because both driving and conversation were highly routine for these participants. These results suggest an *a priori* definition of conversations that impair driving performance and a short set of guidelines for judicious use of cell phones while driving:

- Guideline 1: Remember that your brain can plan only one response at a time.
- Guideline 2: Getting a call during which someone talks to you is better than making a call during which you do the talking.
- Guideline 3: Avoid conversations about complex topics that require decisions, calculations, explanations, or description.

The subjective results indicated that drivers are not aware of the different effects of conversational role and complexity on their driving performance. In this case, the study suggests that public education of drivers about these effects would be valuable.

Future Research

A good follow-up to this study would be one that provides more distinct levels or categories for the factor treated as complexity in this study. Although the data showed trends in the expected directions, none of the effects was statistically significant. Complexity is a difficult factor to manipulate and control within the context of naturalistic conversation. Other approaches would be to abandon levels in favor of distinct categories of response planning, such as the processing of spatial or sequential information.

Another follow-up might be a 2-step study focusing first on response production (because it is more easily observed), then on planning. Such a study could help isolate elements of response production that affect driving performance, which might then be useful in clarifying the effects of planning.

Another follow-up might use more immediate and specific measures of interference than the aggregate driving performance measures used in this study. Pashler notes in his review that continuous tasks are difficult to study under multi-task conditions. His reasoning is that "aggregate measures of continuous performance are not very useful in discriminating among different underlying causes of interference, because they are simply too gross" (Pashler, 1998, p. 271). What appears to be the absence of interference may actually be adroit scheduling of response-planning resources, which is largely an unconscious process. With appropriate equipment it might, for example, be possible to monitor eye movement or neural activity that can be seen to change when the response-planning mechanism is overloaded. The first step in identifying underlying causes of interference with certainty is to identify reliable and specific indicators of distraction.

Conclusion

Although study results were not statistically significant, they suggest how Role and Complexity may interact in naturalistic conversation to distract drivers and impair driving, as measured by errors per minute and error duration. Talking during conversations that required complex response planning and production consistently impaired driving performance. Conversational elements that demanded little or no response planning had little effect on driving. Although participants were aware that listening and talking might impair their driving, they were not aware that talking might impair driving more than listening.

This study generally supports earlier research showing that conversations that place heavy demands on limited information processing mechanisms may impair driving when driving and cell phone use are combined. It further suggests that Role and Complexity may interact under certain conditions to increase the impairment.

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Appendix A. Participant Screener

Contact Info

Name ________________________________

How do you prefer to be contacted for scheduling purposes? _________

Telephone __________ (home) ___________ (work) ____________ (cell)

Email ___________________

Demographic Info

(Participant is…) Male ____ Female ____

Which age range do you fit into?

___ 18 to 34 ___ 35 to 59 ___ 60+

If "35 to 59 or 70 +" say: "Thank you for your interest, but we're focusing on people between 18 and 34 for this study. Thank again and end the conversation.

Do you have a current driver's license (doesn't matter what state or country)?

___ Yes ____ No

If "No" say: "Thank you for your interest, but we're focusing on drivers this time. Thank again and end the conversation.

Can you provide a photo ID that shows your birthdate?

___ Yes ___ No

If "No" say: "Thank you for your interest, but we're focusing on drivers who are between 18 and 34 for this study. Thank again and end the conversation.

How many days a week do you drive?

___ 4, 5, 6, or 7 ___ fewer than 4

If fewer than 4 say: "Thank you for your interest, but we're focusing people who drive a lot for this study. Thank again and end the conversation.

On a scale of 1 to 5, with 1 being very low and 5 being very high, how would you rate your driving ability?

___ 1 (very low) ___ 2 ___ 3 (average) ___ 4 ___ 5 (very high)

Say "OK" and continue.

Do you have a cell phone?

___ Yes ___ No

If "No" say: "Thank you for your interest, but we're focusing on people who use cell phone for this study. Thank again and end the conversation.

Is your phone a hands-free model or do you hold it in your hand when you talk?

___ Hands free ___ Hand held

Say "OK" and continue.

How often do you drive and talk on the cell phone at the same time?

___ Never ____Very seldom ___ Sometimes ___ Often ___ All the time

Say "OK" and continue.

(Explain that the research is being done in Cupertino. Ask if that will be a problem.)

If it's a problem, say "Thank you for your interest, but we need people who can come here for the study" and end the conversation.

(Decide whether the person's English is fluent enough to do the study.)

If not, say "Thank you for your interest, you may fit into the group we're looking for this time. I'll contact you again within 48 hours to let you know" and end the conversation.

Conclusion

Say: "Thank you. You fit into the group of people we're looking for this time. Let me give you the details about the schedule and location, then we can schedule your session."

Appendix B. Agreement to Participate in Research

San José State
UNIVERSITY

Department of Industrial
& Systems Engineering

Room 283, Engineering Building
One Washington Square
San José, CA 95192-0085
Voice: 408-924-3301
Fax 408-924-4040
E-mail: isengr@email.sjsu.edu
http //www.engr.sjsu.edu/ise

Agreement to Participate in Research

Responsible investigator(s): Melissa Sleeter
Title of Protocol: Cognitive Demands

1. You have been asked to participate in a research study investigating the effects of the cognitive demands of doing secondary tasks during simulated driving.

2. You will be asked to interact with a PC-based driving simulator and car stereo and to hold simulated conversations with another person. The session will be followed by a short debriefing session.

3. No risk to you during this session is anticipated.

4. No discernable direct benefits to you will come from this research. However, an indirect benefit may be this research helps to establish guidelines for safely talking on cell phones while driving (or to determine that it is never safe to talk on cell phones while driving).

5. Although the results of this study may be published, no information that could identify you will be included.

6 There will be no compensation for participation in this research.

7. Questions about this research may be addressed to Melissa Sleeter at 408-862-2911. Complaints about the research may be presented to Dr. Kevin Corker, Director of the Graduate Program in Human Factors/Ergonomics, Industrial & Systems Engineering Department, College of Engineering, at (408) 924-3988. Questions about research subjects' rights, or research-related injury may be presented to Pam Stacks, Interim Academic Vice President, Graduate Studies and Research, at (408) 924-2480.

8. No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to "not participate" in the study.

9. Your consent is being given voluntarily. You may refuse to participate in the entire study or in any part of the study. If you decide to participate in the study, you are free to withdraw at any time without any negative effect on your relations with San Jose State University or with any other participating institutions or agencies.

10. At the time that you sign this consent form, you will receive a copy of it for your records, signed and dated by the investigator.

11. You have provided a photo ID confirming that you are at least 18 years old.

- **The signature of a subject on this document indicates agreement to participate in the study.**

- **The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his or her rights.**

______________________________ ____________
Signature Date

______________________________ ____________
Investigator's Signature Date

Appendix C. Instructions to Participant

Greeting (10 minutes)

When the participant arrives, the experimenter introduces herself, reviews the consent form and checks the participant's driver's license and age (must be at least 18), and provides a cover story. During the greeting, the experimenter's script is as follows:

- Hello, my name is…. Welcome to our driving simulator study. We are evaluating the usability of a driving simulator under normal driving conditions.

- Before we start, there is a consent form that you'll need to read and sign. (Briefly review the major points of the form.) Also, I'll need to verify that you are at least 18. Did you bring your driver's license with you? (Write birthdate and license number on the consent form.)

- I'll give you a couple of minutes to read and sign the form.

- Do you have any questions at this point? (If not, take the participant into the lab.)

- Here is our simulation lab. This is the simulator you'll be driving today. You'll watch the road on this monitor and respond to what's going on using the steering wheel and foot pedals. You have a gas pedal (on the right) and a brake pedal (on the left). While you are in here driving, I'll be in another room (show the participant) on the other side of the mirror. This is so I don't distract you.

- In addition to driving today, I'll have conversations with you as if we were talking on cell phones. During our conversations, we'll use an open microphone to simulate using a hands-free cell phone. Here's how the ring will sound....

- For the conversations, I'll ask some questions to get us started or keep things moving. Pretend that you're driving a real car in a real city and talking to a friend. It's fine to ask me questions, too.

- Unless you're having a cell phone conversation, just keep driving normally as best you can, and always following the rules of the road, posted speed limits and signs, etc.

- Now I'll show you the simulator. (At this point, show the participant how to use the simulator—speed up, slow down, stop, toggle between reverse and drive, check the rear- and side-view mirrors. Let them try the controls.) Steering wheel control buttons below:

Look Left (3) Look Right (2)

Reverse/Drive (1) Rear View mirror (2)

Look Back (5) Horn (6)

- OK, before you start practice driving, remember to drive as you normally would—as safely as possible and following all the rules of the road:

    - Respond to all traffic signals, sign, and other events as you would on the road.

- Avoid collisions, even if you have to take drastic action.
- Drive at the speed limit. The sign is posted over here. The limits are 45 MPH on city roads and 65 on the freeway.
- Stop as smoothly as possible when you need to stop.
- Stay in your own lane.
- Check your read and side mirrors when passing, turning left, or merging.

• Also note that there are some differences between this simulator and an actual car. In fact, it is admittedly much harder to drive here than in a real car, so don't be embarrassed if you find it somewhat difficult to control. One major difference is that you don't have side windows. Another difference is that you don't have any turn signals—so that is one typical driving behavior that we won't ask you to do today. Remember that it's a game. You may hit cars or get hit, so do your best to keep driving. Don't sit at an accident site. Try to go around it and get back on your route.

• That's it. Do you have any questions?

Practice (10 minutes)

During practice, the experimenter's script is as follows:

- This first driving task gives you a chance to get familiar with the way the driving feels using a simulator. Whenever you are ready, just start the car and begin driving. I'll let you know when to stop.

- It's about time to start the driving session now. We'll take a break in half an hour, about halfway through the session. But if you need a break at any other time, just let me know. It's easy to start and stop the simulation. Do you have any questions before we start?

Driving Task (60 minutes, with conditions interspersed)

During the driving task, the participant experiences all of the experimental conditions. The experimenter's script is described below. Note that conditions are interspersed, so times are cumulative rather than continuous.

Driving Only (30 minutes)

The experimenter does not initiate any conversation during the "drive" periods.

Driving While Conversing via cell phone (30 minutes)

During this condition, the experimenter initiates simple or complex conversations on various topics. The driver continues to drive while listening and talking. As the table below shows, presentations are counterbalanced. Everyone begins by driving for 5 minutes, then conversational prompts are grouped in 8-minute topical "conversations"

(C1, C2, C3, and C4) and interspersed with 5-minute drive-only periods. For a detailed script of conversational prompts, see Appendix E (Conversation Prompts).

Wrap Up

At the end of the hour, the experimenter's script is as follows:

- OK, we're done with the session. I'll be right in.
- To wrap up the session, I'm going to ask you to give us some written feedback on this survey. Take a minute to look at it and let me know if you have any questions. I'll give you a few minutes to complete the survey. Let me know when you've finished and I'll ask you to sign the blue participation sheet.
- Thanks very much for your participation in the study.

Appendix D. Post-Session Survey

1. Please rate your overall driving performance during this session.

1	2	3	4	5
Very Poor	Somewhat Poor	Average	Somewhat Good	Very Good

2. How easy or difficult was it to safely drive this car simulator while you were driving only and not performing any other task?

1	2	3	4	5
Very Difficult	Somewhat Difficult	Average	Somewhat Easy	Very Easy

3. How easy or difficult was it to safely drive this car simulator while talking to another person?

1	2	3	4	5
Very Difficult	Somewhat Difficult	Average	Somewhat Easy	Very Easy

4. How easy or difficult was it to safely drive this car simulator while listening to another person?

1	2	3	4	5
Very Difficult	Somewhat Difficult	Average	Somewhat Easy	Very Easy

5. Were there any aspects of particular conversations you had during this session that made driving safely more difficult?

___ Yes ___ No

If Yes, please describe.

6. What, if anything, do you feel affected your driving during the session?

7. Does conversing while driving have a negative effect on your driving performance?

____ Yes ___ No

8. Were some of the conversations we had today more difficult to engage in while driving than others?

____ Yes ___ No

If Yes, please list them.

9. On a scale of 1 to 5, with 1 being very low and 5 being very high, how distracting was it to drive the simulator while <u>talking</u> to another person?

__ 1 (very low distraction) __ 2 __ 3 (average) __ 4 __ 5 (very high)

10. On a scale of 1 to 5, with 1 being very low and 5 being very high, how distracting was it to drive the simulator while <u>listening</u> to another person?

__ 1 (very low distraction) __ 2 __ 3 (average) __ 4 __ 5 (very high)

That's it! Thank you for your feedback!

Appendix E. Conversation Prompts

C0—Phone Check	S/C	Response
[Ring…]		
Hi [Name], it's Melissa. I just wanted to try out the cell phone. Could you hear the ring OK? Am I coming in clear?		
OK. Keep driving and I'll call you a bit later.		
Bye.		

C1—Simulator / Driving / Cell Phones	S/C	Response
[Ring…]		
Hi [Name], it's Melissa.		
I just thought I'd call and see what you were up to. What are you doing?	S	report
Where are you?	S	report
[sim…] You know you're driving in Simulated Chicago. Have you seen the "el" —the elevated trains–running overhead?	S	recall
[sim..] And The Loop—all the way around the city? You're driving it now.	S	recall
[sim…] Have you ever been to Chicago?	S	recall
[sim…] What do you think of it so far?	C	explain
[SF…] Do you get up to San Francisco often?	S	recall
[SF…] Where'd you go last time you went?	S	recall
[SF…] What's the best way to get to San Francisco?	C	sequence
[sim…] Have you ever driven a simulator before? When?	S	recall
[sim…] How does this simulator compare to real driving? The steering wheel responsiveness? The brake action? How about speeding up and slowing down?	C	compare /contrast
[sim...] There is a fairly new piece to simulation, called *haptic* or *force* feedback. Have you ever driven a simulator or game that provides haptic feedback? (definition: a method for providing physical constraints in a virtual world. Tactile feedback provides a sense of touch through, typically, vibrating nodules or expanding air bubbles inside a glove or suit. Force feedback provides physical constraints.)	S	recall
[sim…] Where could this simulator use haptic feedback to make the experience more realistic?	C	decide /describe
[sim…] What kind of car are you driving now? What color?	S	report
[car…] What kind of car do you drive? What color?	S	recall
[car…] Is it your first car? How did you get your first car (this car).	C	describe
[car…] If you could have any kind of car you wanted, what would you get? Why?	C	decide /explain
[car…] I've read that cars cost almost twice as much as they did 30 years ago, in terms of percentage of your income. Why do you think that is?	C	compute
[car...] Here's a design challenge: If I asked you to design a car that was affordable again, how would you do it? What's something you'd redesign or take out.	C	decide /describe
[commute…] How's your commute?	S	recall

C1—Simulator / Driving / Cell Phones (continued)	S/C	Response
[commute…] Describe your commute route.	C	sequence
[driving…] About how many miles do you think you drive each month?	C	compute
[driving…] I once considered leasing a car until I found out that they would charge me 10 cents for every mile I drove over 12,000 miles a year. At your average weekly mileage, do you think leasing would be a good idea for you?	C	compute
[car…] I'm on my way to look for a new car. My commute's really long, so I'll look at hybrids if I can remember who makes them. Do you know?	S	recall
Oh, I'm almost to the Honda dealership now. Keep driving; I'll call back later. Bye.		

C2—Personal technology / Internet	S/C	Response
[Ring…]		
Hi [Name], it's Melissa.		
I had to call about great web site I just saw. It's called www.subservientchicken.com. A guy dressed in a chicken suit will whatever you tell him—most of the time. He dances; he moonwalk;he goes to sleep. But if you tell him to do something naughty, he comes up close to the camera and bends down really close, then wags his finger, and shakes his head. You've gotta see it.		
[funny web sites…] You seen any funny web sites lately? What?	S	recall
[funny web sites…] What kind of humor do you enjoy? I might know some other sites you'd like.	C	describe
[Internet…] Do you go on the Internet much?	S	recall
[Internet…] To do what?	S	recall list
[chat...] What was the last chat room you visited?	S	recall
[chat…] What was the conversation about?	S	recall
[chat…] Well, you can't see the people in the room? How do you get a sense of what they're like? How do they compare to people you know other places?	C	compare /contrast
[chat…] What makes chatting interesting—keeps you coming back to the same room?	C	decide /explain
[blogs…] Do you know about Weblogs/blogs?	S	recall
[blogs…] What are they for?	C	describe
[blogs...] What was the last blog you went to?	S	recall list
[blogs…] What was it about?	S	recall list
[blogs…] What makes a blog interesting—keeps you coming back?	C	decide /explain
[shopping…] What kind of stuff do you shop for online?	S	recall
[shopping…] What were the last couple of online stores you visited?	S	recall
[shopping…] What are the pluses and minuses of shopping online vs. in a real store?	C	compare /contrast
[shopping…] So what if you don't like what you get, if it doesn't work or doesn't fit—what do you do then?	C	explain process
[shopping…] Do stores you buy from keep sending email ads forever? Who?	S	recall

C2—Personal technology / Internet (continued)	S/C	Response
[shopping…] What did you do about it?	C	explain process
[buy music online…] Ever buy music online? Or not buy it? download it?	S	recall
[buy music online…] Can you still download music? Is is safe? What about movies or videos?	S	recall
[buy music online…] Where are some good places to do that?	S	recall list
[buy music online…] How does buying the music work? How do you actually get the music onto the player?	C	explain process
[buy music online…] Do you have an MP3 player or iPod? Is it a good value for the money or is there a better one on the market now? If you upgraded, what would you go to?	C	compare /contrast
[web sites…] Have you ever created a web site? What was it for?	S	recall list
[web sites…] What kind of content did you use? Text, obviously. But what about pictures? Animation?	S	recall list
[gaming…] What game have you played recently?	S	recall
[gaming…] Do you play that alone or with other players?	S	recall
[gaming…] Explain how that game works. I've never played it.	C	explain a process
[ISP…] Who's you Internet provider? Have you tried others?	S	recall list
[ISP….] For a while DSL was replacing the broadband cable modems, but not broadband seems to be coming back. Why do you think that is?	C	compare /contrast
[email…] What about email? What kinds of accounts do you have? Or have you had?	S	recall
[email....] I read about Google's Gmail. It's free and reviewers say, "It's fast, easy on the eyes, and a treat to use." But Google plans to deliver ads based on the scanned contents of your email. What's the advantage of it? Or is there one?	C	decision
[cell phone…] I'm gonna go look for a new cell phone. Mine's old. What should I look for?	C	decide /describe
[cell phone…] How long have you had your phone? Have you though about upgrading?	S	recall
[cell phone…] What features do you want when you upgrade? How do they compare with your phone's features?	C	compare /contrast
[cell phone…] Would you change providers or just phones?	C	decide
[handheld…] How does that [whatever operation] work?	C	explain process
[handheld…] Which one would you have if you could buy anything? Why?	C	compare /contrast
Uh-oh, I'm losing the signal on my phone. You're fading in and out. I'll call later. Bye.		

C3—TV / Politics / Movies / Celebrities	S/C	Response
[Ring…]		
Hi [Name], it's Melissa.		
Hey, I bought a new car—a moss green Honda mini-SUV. It gets about 38 miles per gallon. And it's got a satellite TV that folds down from the roof. The kids can watch in the back seat.		
[TV…] Do you get a chance to watch much TV? When, usually?	S	recall
[Reality TV…] What about Reality TV?	S	recall

C3—TV / Politics / Movies / Celebrities (continued)	S/C	Response
[Reality TV…] Which ones have you seen?	S	recall
[Reality TV..] Are there reality shows that you watch faithfully?	S	recall
[Rcality TV…] What's thc attraction? What do thcy havc in common that appcals to you?	C	intcrprct
[TV...] What other kinds of shows do you watch a lot? —sitcoms? real crime? science fiction? old reruns (Lucy)? game shows? sports? fantasy (Buffy)? documentaries?	S	recall
[TiVo…] Have you experienced TiVo yet? [definition: a computer-like device that "learns" what TV shows you watch and begins to automatically capture them for watching on demand.]	S	recall
[TiVo…] Did you like it? Why / why not?	C	explain
[news…] What news channels do you watch?	S	recall
[news…] What's caught your attention lately on the news?	S	recall
[news…] What do you think about [something about the topic]?	C	explain
[Iraq…] We keep hearing comparisons of Iraq with the Vietnam War. What's your notion about what Vietnam was like? About how and why it happened?	C	interpret
[Iraq...] In addition to military troops, there are private "guards" or mercenaries who fight for pay. Dozens of private security companies have set up shop in Baghdad and are hiring out groups of security troops. The estimated is 20K in addition to 130K official soldiers. What effect do you think their presence will have?	C	decide
[Iraq…] Do you know anyone stationed in Iraq?	S	recall
[movies…] What are the last 3 movies you've seen?	S	recall list
[movies…] What did they have in common that appealed to you?	C	compare
[movies…] How would you describe your taste in movies? Enough that I could rent a movie that you'd like.	C	explain
[movics…] Thcrc arc scvcral movics coming out this summcr? Any you want to scc?	S	rccall
[movies…] What's your favorite movie of all time?	C	decide
[movies…] Have you seen the Passion of the Christ?	S	recall
[movies…] What was your take on it?	C	interpret
[celebrity…] Who are your favorite movies stars or celebrities?	S	recall
[celebrity…] Why?	C	explain
[celebrity…] Who's really outrageous? What about Paris Hilton? Or Michael Jackson?	S	recall
[celebrity..] What makes him/her outrageous?	C	explain
[fame…] If you ever become famous, what would you see as the pros and cons of it?	C	explain
[fame…] If you could choose to be rich and famous or just rich, which would you choose? Why?	C	decide /explain
Hey, I've gotta go for now. Talk to you later.		

C4—Sports / Hobbies / College	S/C	Response
[Ring…]		
Hi [Name], it's Melissa.		
Are you still in Chicago? I'm on my way to the hockey playoffs.		
Do you like sports? What's your favorite?	S	report
[sports…] What was the last game you went to or watched?	S	recall
[sports….] What about your favorite team and player?	S	report
[sports…] Take a guess at his yearly salary.	S	recall
[sports…] What makes the team special?	C	explain
[baseball...] We've all been following Barry Bonds home run count lately. But I read this in the newspaper the other day: "The most glaring difference between Barry Bonds and Babe Ruth is that at the beginnning of his career, Ruth was a Hall of Fame-caliber pitcher. What's your take on that?	C	explain
[baseball…] If Barry Bonds failed a test for steroids, what do you think the consequences should be—assuming that there would have to be some consequences?	C	decide
[sports…] I think sometimes, people who really deserve recognition don't get it. Who do you think is the most unrecognized player or team in sports? Or even the most unrecognized sport?	C	decide /explain
[sports…] What other sports do you like—[soccer? golf? football? bowling]?	S	recall
[sports…] What attracts you about those?	C	explain
[sports…] When you were growing up did you play sports? In an organized league?	S	recall
[sports…] What do you think of organized sports for kids?	C	explain
[sports…] Do you play anything now? At what level?	S	recall
[hobby…] Do you have a favorite hobby or activity? Or something you've always wanted to do when you get around to it? Something you used to do? —biking? Rock climbing? gardening? ballroom dancing?	S	recall
[hobby…] How did you (do you plan to) learn to do that?	C	explain process
[hobby…] Sounds like a big investment in equipment...	S	recall
[board games…] Here are the top-selling board games in the US: Trivial Pursuit, Cranium, Monopoly, Scrabble, The Game of Life. Have you played any of these? Or other board games?	S	recall
[board games..] I've never played that. How does it work?	C	explain process
[activity..] What else do you do in your "copious free tme"? —books, drama, concerts, nightclubs?	S	recall
[activity…] What good [books, drama, concerts, nightclubs] have you [read, seen, gone to] in the last month or so? What made an impression on you?		
[classes…] What classes did you take this semester?	S	recall
[classes…] Everyone I've ever known (including me) changes majors at least once? Have you chosen a major yet or picked one and changed it?	S	recall
[classes…] What's been your best class so far? Why?	C	decide /explain

C4—Sports / Hobbies / College (continued)	S/C	Response
[classes..] The worst? Why?	C	decide /explain
[college…] Where did you look before picking San Jose State?	S	recall
[collcgc…] What madc you pick San Josc Statc?	C	comparc /contrast
[library…] I have to tell you—I love the new King Library. Have you spent much time there?	S	recall
[library…] What's your favorite thing about the new library? Why?	C	decide
[library…] it seems to have lots of "gadgets." Have you seen the moving shelves down on the bottom floor? How do they work?	C	explain process
[library…] Have you used the electronic checkout?	S	recall
[library…] How does that work?	C	explain process
[library…] What do the students say about it?	S	recall
[library…] What's the old Clark Library being used for now?	C	explain
[parking…] Last time I bought campus parking, it cost me $80 AND I could never find a spot. What are they charging now?	S	recall
[career…] What do you plan to do after college? 15 years from now?	C	describe
[career…] Where and how would you like to live?	C	describe
Well, I'm at the arena now. Gotta go. Bye.		

Appendix F. SJSU Human Subjects Institutional Review Board Permission

San José State
UNIVERSITY

Office of the Academic Vice President

Academic Vice President Graduate Studies and Research

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San José, CA 95192-0025
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To: Melissa Sleeter
16214 Oleander Avenue
Los Gatos, CA 95032

From: Pam Stacks, Pam Stacks
Interim AVP, Graduate Studies & Research

Date: November 24, 2003

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"The Cognitive Demands of using a Cell Phone while Driving."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Pam Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year and data collection beyond November 24, 2004 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

cc: Dr. Anthony Andre